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Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17-21 September 1984

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Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17–21 September 1984

Editor: Jackson A. Kategile

Cosponsored by the
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and the
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Abstract: The proceedings contains reviews by national scientists on pasture research done primarily in Eastern and Southern Africa (Ethiopia, Kenya, Tanzania, Burundi, Zambia, Zimbabwe, Swaziland, Lesotho, Botswana, Mozambique, and Madagascar). The application of the results obtained and lessons learned are highlighted and used in setting of national priorities for research areas for the future. Critical reviews on current pasture research methodologies are included in the proceedings. The research methods discussed are germ-plasm collection, storage, and dissemination; and germ-plasm introduction and evaluation, nutritive evaluation of pastures, grazing experiments, and range monitoring. Specific guidelines on methodologies are outlined and these are useful to pasture agronomists, animal nutritionists, and range-management scientists.

Two case studies of pasture-research regional networks in Asia and Latin America were presented and discussed. A strategy for future pasture research coordinated through a regional Pastures Network for Eastern and Southern Africa (PANESA) was discussed and agreed upon.

Résumé: Dans les actes ci-joints, des scientifiques de divers pays analysent la recherche entreprise sur les pâturages en Afrique orientale et australe (Éthiopie, Kenya, Tanzanie, Burundi, Zambie, Zimbabwe, Lesotho, Botswana, Mozambique et Madagascar). L'utilisation des résultats obtenus et les connaissances acquises sont mises en lumière, puis utilisées pour établir les priorités nationales en matière de recherche. Les actes comportent une analyse critique des méthodes de recherche actuelles sur les pâturages : rassemblement, entreposage et diffusion du matériel génétique; mise à l'essai et évaluation de ce matériel; expériences de pâturage; évaluation nutritive des pâturages et exploitation rationnelle de ceux-ci. On présente des lignes directrices précises sur les méthodes à suivre, qui seront utilies aux agronomes en charge des pâturages, aux spécialistes de la nutrition animale et aux scientifiques responsables de la gestion des pâturages.

Deux études de cas ont fait l'objet d'une présentation suivie d'une discussion : il s'agit des réseaux régionaux de recherche sur les pâturages en Asie et en Amérique latine. Après discussion, on a convenu d'une stratégie de la recherche sur les pâturages, dans les années à venir; la coordination de cette stratégie sera assurée par une section régionale du Pastures Network for Eastern and Southern Africa (PANESA).

Resumen: En las actas se recogen ponencias presentadas por científicos de diferentes países sobre las investigaciones en pastos que se han realizado principalmente en el Africa oriental y meridional (Etiopía, Kenia, Tanzania, Burundi, Zambia, Zimbabwe, Suazilandia, Lesotho, Botswana, Mozambique y Madagascar). Se destaca la aplicación de los resultados y experiencias obtenidos, muy útiles para determinar las prioridades de las investigaciones futuras en las diferentes naciones. En las actas se recogen también ponencias críticas sobre las metodologías empleadas actualmente en las investigaciones sobre pastos. Se analizan los siguientes métodos de investigación: recogida, almacenamiento, diseminación, introducción y evaluación de germoplasma; evaluación del valor nutricional de los pastos; experimentos de pastoreo; y control de dehesas. Se resumen directrices y metodologías específicas de gran utilidad para agrónomos especializados en pastos, expertos en nutrición animal y científicos especializados en gestión de dehesas.

Se presentan y analizan dos estudios de casos de las redes regionales de investigación en Asia y Latinoamérica. Se discutió y aprobó una estrategia para realizar investigaciones sobre pastos en el futuro que serán coordinadas por la Red de Investigaciones sobre Pastos para Africa Oriental y Meridional (RIPAOM).

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FOREWORD

It is well acknowledged that animal production is an important component of traditional agriculture in Africa, particularly among the pastoralists and agro-pastoralists. Besides supplying animal protein from milk, eggs, and meat, animals provide an important part of the cash income from smallholdings. Through manure, cash availability, and draft power they greatly influence the ability of farmers to produce food and cash crops. Animal production complements arable cropping. Traditionally, animals are raised on marginal lands, unsuitable for arable cropping, and manure is often concentrated in small areas dedicated to cropping. Increasingly, animals are fed with field crop residues or agricultural by-products.

Animal productivity in Africa is still low, and few changes have taken place in the last several decades. Not surprisingly, animal protein supplies have dwindled with time, particularly in the rural areas as human populations increased and market outlets into urban centres attracted the major share of livestock products. Many production factors contribute to low animal productivity in the smallholder sector, but it is recognized that inadequate nutrient supplies is an overriding factor. Grazing makes up the bulk of feedstuffs and comprises the cheapest feed resource. The dominant role of pastures in livestock production systems is unlikely to change, and, therefore, improvement of pastures is pivotal to livestock development in the smallholder or communal sector.

As population increases, the area required for food crops expands. To ensure continued supply animal traction and manure for the food-production system, improved pasture species will have to be planted in much closer association with crops. Increasingly, livestock will obtain its feed from arable land managed by individual families, because the contribution of the rapidly degenerating communal grazing lands will become insufficient to sustain the cattle needed for stable crop production. Pastures must, therefore, change from natural or hardly managed stands, to more intensely managed, frequently rotated, specialized pastures with specific traits.

This publication describes the proceedings of a meeting of pasture scientists in Eastern and Southern Africa. The meeting convened to review pasture research, discuss research methodologies, and draw up a regional strategy for research on the improvement and management of pastures for the small-scale farmer. I hope that the activities planned as a result of this meeting will stimulate interest among pasture scientists and will lead to a better understanding of the type of pasture species and the management required to increase the feed availability for cattle and the land quality in smallholding and communal areas in Eastern and Southern regions.

The special efforts of Drs Jackson Kategile and Gerry Grant in the preparation of this workshop are gratefully acknowledged. The organizers are most grateful to Dr Philip Chigaru for hosting the sessions and the Department of Research and Specialist Services of the Zimbabwe Ministry of Agriculture.

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KEYNOTE ADDRESS
SOME ISSUES FACING PASTURE RESEARCH WORKERS IN AFRICA

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At a gathering of this kind, at which expert agriculturalists from various countries in sub-Saharan Africa have been brought together, I believe it is pertinent that we must start by reminding ourselves of the major food crisis that our continent is facing. It is now common knowledge that during the past decade, food shortages have proliferated in sub-Saharan Africa. Indeed, ours is the only region in the world that has exhibited a consistent decline in food production during the past 12 years. The decline has amounted to about 10% over the period.

In April 1983, a special FAO/World Food Programme study was commissioned to review and monitor the food and crop situation in sub-Saharan Africa. As a result of this study, FAO launched an appeal for food aid for several African countries. Since then, the prospects for food availability in 1984-85 have deteriorated even further.

If one examines the rates of growth in population along with the rates of growth in agricultural production, the situation is even more alarming. During the period 1960-82 population has been rising steadily while agricultural production was falling at a time when it needed to increase.

When the implications of these statistics are examined further, the situation is very grim indeed because the great majority of African people depend on agriculture for their livelihood. Thus, with falling production and increased population, our people have been becoming poorer with each passing year, with the overall situation being exacerbated by drought conditions during the past few years. They have also been facing increased hunger and malnutrition in many countries.

Those who are not familiar with the situation I have portrayed may wonder what relevance these statistics have on this workshop on pastures. As stated by the Minister, pasture work should be an integral part of livestock research because its goal is to increase livestock production and productivity through enhanced availability of nutrients from grassland. In many countries in Africa, livestock and livestock products are a principal means of subsistence. Indeed, the demand for meat and milk has increased rapidly in Africa during the past decade as witnessed by the dramatic increase in imports of these products. This increase in imports of livestock products has been additional to the large imports of cereal grains over the same period.

Increases in the importation of livestock products have occurred because the output of meat and milk from sub-Saharan Africa's ruminant livestock population has not kept pace with the growth of the human population and the increase in demand, particularly in the urban areas. The major reason for this low output is that the productivity of livestock in Africa is very low. According to informed estimates livestock production in this continent can be increased at least five-fold by adapting known technologies and special farming systems to the special needs and conditions of tropical Africa.

LIVESTOCK PRODUCTION SYSTEMS IN AFRICA

In sub-Saharan Africa, the total population of ruminant livestock (cattle, sheep, and goats) is estimated at about 300×10^6. The unique economic value of these ruminants is their ability to make productive use of soils and vegetation that would otherwise yield nothing of importance to humans. In addition to meat and milk, ruminants in tropical Africa also provide hides and hair, traction and transportation, and fertilizer and fuel. They also serve as vehicles for investment, savings, and capital formation. In most societies, livestock also figure importantly in social relationships and rituals.

Sub-Saharan Africa is also characterized by a wide diversity of agroecological conditions not only between countries but also within countries. Thus, livestock production systems and the productivity of the livestock, will vary from one country to another and from one subregion of a country to another.

It is clear, however, that in the absence of major animal diseases, nutritional stress is the major constraint to increased livestock production. The main source of nutrients for ruminants is veld or natural grassland. The quantity and quality of the herbage available from this grassland is determined by many factors with rainfall and soil type being the major determinants. Both these factors will affect not only the nutritive value of the herbage but also the herbage species composition in any given area.

Irrespective of rainfall and soil type, however, an additional factor that is of paramount importance is the management of natural grassland by the farmers whose livestock use that grassland. Management includes such components as the grazing system utilized, the stocking rates applied whether or not fertilization of the grassland is practiced, and whether or not other foods in the form of supplements are available for the livestock. In this last instance, it is important to recognize that much of Africa's livestock production is associated with cropping with cereal crops being the main crops grown. Consequently, there is the need to exploit this link between livestock and cropping as fully as possible to stimulate increases in both crop and livestock output. It appears that this can be accomplished effectively through the use of legumes. Work in some parts of Africa shows that apart from rotating cereals with legume leys it is possible to grow them in alleys between rows of browse legumes or to intercrop them with forage legumes. In these systems, both legumes and food crop residues would be used as feed for livestock particularly during the long dry periods characteristic of most of Africa.

It is not possible to review all the livestock production systems that are found in sub-Saharan Africa in this address. However, to illustrate the problems that we as agricultural scientists face in increasing livestock production in our various countries, I shall use the situation in Zimbabwe as an example. The Zimbabwean situation may or may not be relevant to other African countries but the problems should be similar in many respects.

Structurally, the livestock industry in Zimbabwe, and indeed the whole of the agricultural industry, can be divided into the following categories: (a) large-scale farms held by individuals under free-hold tenure or by the state and cooperatives, and (b) the communal or peasant areas farmed under traditional tenure. Since independence in 1980, a third group of farmers is emerging in the resettlement areas that are made up of large-scale farms bought by government and settled with landless peasants or people removed from the communal areas with the aim of diffusing population pressures. For the purposes of this discussion, however, this group of farmers will not be discussed because it is not yet possible to assess their situation to determine if their needs and problems differ from those of the two groups I have delineated.

LARGE-SCALE COMMERCIAL SECTOR

The large-scale sector is characterized by sophisticated livestock enterprises whose production and productivity compare favourably with that in developed countries. The sector is highly monetized and historically has had a relatively sound infrastructure and reasonable access to credit and inputs. In addition, farmers in this sector are literate and exhibit a clear desire and ability to adopt improved technology. Economies of scale are also in their favour.

Between 1965 and 1977, there was dramatic growth in beef production in the large-scale sector. Numbers of animals kept in this sector increased from 1.6×10^6 in 1965 to 3.1×10^6 in 1977, an increase of about 90%.

This growth occurred as a result of the policy of diversification introduced by the government of the day in response to the threat of mandatory United Nations sanctions against Rhodesia. To reduce the country's dependence on tobacco, which was an obvious target for sanctions because almost the entire crop was exported, considerable research and extension effort was put into methods of increasing the productivity of beef cattle and into the adoption of better husbandry practices by formerly predominantly tobacco growers.

Thus, methods were derived, particularly in the higher rainfall areas of the country, to integrate livestock, natural grassland, planted pastures, crops (particularly maize), and crop residues into intensive systems of beef production. Similar measures were taken with dairy cattle but milk production did not expand to the same extent as beef production.

Through research and extension, therefore, it has been possible to transform livestock production in the large-scale sector. It is this sector that produces the high-quality beef for which Zimbabwe is renowned. At present the country is exporting both beef and dairy products and is keenly awaiting the agreement of the European Economic Committee (EEC) to export 8,100 t of beef annually under the Lome convention.

COMMUNAL SECTOR

In the communal or peasant areas livestock numbers also increased dramatically from 1.8×10^6 in 1965 to 3.4×10^6 in 1977, an increase of approximately 80%. This increase in livestock numbers, however, went hand in hand with an increase in the human population without any concommitant changes in the size of available land. Therefore, from 1960 to 1980, the trend has been one of increasing cattle numbers and decreasing grazing resources as a result of increased cropping to satisfy the food needs of a rapidly expanding peasant population. In many areas of the country, human and livestock populations became, and still are, greatly in excess of the carrying capacity of these areas. Serious degradation of the country's natural resources began to occur, and, recently, this has been exacerbated by the drought. An important additional factor is that about 90% of the communal area farmers farm in Natural Regions IV and V, which include the poorest areas of the country in terms of rainfall and soil fertility.

In the past, and particularly since 1952 when the Land Husbandry Act was promulgated, various strategies have been devised with the objective of effecting certain desired changes in the system of livestock production in the communal areas. Most of the strategies have focused on controlling stock numbers through enforced destocking. So far, this has failed.

Also of importance is the low productivity of communal area livestock. It is estimated that the calving percentage of communal area cattle is less than 35% compared with about 65% in the large-scale sector cattle. Cows in the communal areas also calve once every 2-3 years. The main reason for this poor performance appears to be the lack of adequate nutrition particularly during the 8 month long dry season. Growth rates of young stock are also low for the same reason.

The situation in Zimbabwe's communal areas is similar to that in other African countries and poses a great challenge to agriculturalists. What has not been helpful to agriculturalists in Zimbabwe, and perhaps elsewhere in Africa, is the lack of a clearer understanding of the complexity of the role of cattle in the communal areas.

Livestock, particularly cattle, are now recognized as an important capital item in communal area farming systems. With grazing being a free resource under traditional tenure, more cattle have tended to be kept with resultant overstocking and overgrazing. There is no reasonable reward under this tenure system for reducing cattle numbers. Indeed, the attraction of investing in cattle in the communal areas is further illustrated by the fact that a proportion of cattle found in any given area are owned by people who are not communal farmers but reside and work in urban and other areas such as mines and large-scale farms.

In addition, when communal farmers want to dispose of cattle, they usually sell older animals that are no longer required for draft or reproduction purposes. This behavioural pattern is not necessarily uneconomic. On the contrary, this can be viewed as a means by which the farmer seeks to maximize output and the total return to capital value can be substantial.

Although other forms of livestock have not been mentioned, they can also be of importance particularly with respect to their impact on grazing resources. In economic and social terms, however, they are not as important as cattle.

Given the main characteristics of livestock production in the communal areas of Zimbabwe, the question arises: How should we proceed to intervene technologically to effect improvements in the production and productivity of these livestock on a sustainable basis? In effecting given improvements how do we simultaneously ensure that the country's natural resources are conserved for the benefit of all the country's inhabitants and the future well-being of those to come?

There is active debate on these issues in Zimbabwe at present and I am sure that this situation is exercising the minds of all participants here with respect to their own countries. As stated before, it is clear that the major constraint to improved animal production in Africa is nutrition. Without any meaningful improvement in the quantity and quality of grazing, there can be no sustainable basis for improved productivity. Under conditions of traditional tenure and the communal grazing that goes with it, how can this be achieved? This is a question without any easy answers and the way I have stated it rather simplified an otherwise complex situation. However, if we in Africa are to reverse the trends in declining food production in the future, the answer, or answers, must be found. I am confident that this workshop, which has brought together pasture scientists from across Africa and experts from outside the continent, will serve as an important milestone in the quest for answers to this and other difficult questions pertaining to the improvement of livestock production in Africa.

Session I

State of Research Work in Eastern and Southern Africa

PASTURE RESEARCH IN ZIMBABWE: 1964-84

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Abstract *The past 20 years have seen the acceptance in Zimbabwe that the best time to use nitrogen-fertilized grass pastures was during the growing, and not the dry, season. These pastures could remain productive if heavily fertilized and this resulted in massive herbage production and very high carrying capacity. Only stoloniferous or rhizomatous grasses were capable of withstanding very heavy stocking rates and No. 2 Star grass* (Cynodon nlemfuensis) *proved suitable. Management trials showed that continuous, rather than rotational, grazing was the best way to use these pastures. Economic analysis of the results showed that production systems for beef steers incorporating these pastures were profitable.*

The other major development was the demonstration that subtropical legumes could be established in pastures or native grassland in Zimbabwe. Using this legume-rich grazing during the dry season proved wasteful, due to defoliation by frost and to trampling losses, and greatest effects on productivity were obtained for year-round or growing-season grazing. Oxley fine-stem stylo (Stylosanthes guianensis) *proved suitable for grassland reinforcement on sandy soils, Siratro* (Macroptilium atropurpureum) *and Silverleaf desmodium* (Desmodium uncinatum) *for dryland pastures and Kenya white clover* (Trifolium semipilosum) *for irrigated pastures.*

The results of this research have been widely applied on commercial farms in Zimbabwe but have had little effect on communal agriculture.

Agricultural research is the sphere of responsibility of the Department of Research and Specialist Services (DRSS) of the Zimbabwe Ministry of Agriculture. The Division of Livestock and Pastures is one of the three divisions into which the Department is subdivided, the other two being Crop Production and Specialist Services.

The research work of the Division of Livestock and Pastures (which also has various regulatory functions) is centred on four research stations:

. Grasslands Research Station, 7 km W of Marondera, granite sandy soils, 1,600 m altitude, mean annual temperature 16.3 °C, and average annual rainfall 900 mm.

. Henderson Research Station, 10 km S of Mazowe, wide range of soil types but most of the pasture trials were done on silty clay loams, 1,200 m altitude, mean annual temperature 17.8 °C, and average annual rainfall 870 mm.

. Makoholi Experiment Station, 40 km N of Masvingo, granite sandy soils, 1,200 m altitude, mean annual temperature 20.6°C, and average annual rainfall 580 mm.

. Matopos Research Station, 40 km S of Bulawayo, serves the drier regions of Zimbabwe and the work centres on the use of natural grazing. The work of this station is not mentioned in this paper as "pastures" has been taken to indicate grazing in which at least some of the species have been sown. In all cases the rainfall is highly seasonal with about 95% falling in the 5 months from November to March.

On each station there are separate animal production and pasture research teams, but they normally work in close liaison. At 1 August 1984, there were seven professional pasture research officers in the Division, but this number is lower than it has been in the past.

The results of the research work on pastures have been applied almost entirely on commercial farms. As yet, they have been little adopted in peasant agriculture where communal grazing and the absence of defined boundaries to the grazing area of each group are limitations to the use of improved techniques. In almost all cases where peasant farmers have grown improved pasture species, it has been within the arable landholding. In this paper, except where otherwise specified, "farming practice" refers, therefore, to commercial agriculture.

Cattle on native grazing gain livemass during the rains, maintain a constant livemass during the early dry season, and then lose mass during the late dry season. The aim of most of the early pasture research was to fill this winter feed gap, either with conserved feed such as hay or silage or with pastures allowed to mature as standing hay or foggage. This work was generally unsuccessful, and the realization grew that the best time to use expensive sown pastures was when their nutritional quality was greatest during the growing season and to use the native grazing, with a protein supplement if necessary, for winter maintenance.

Initially, it was suggested that pastures should be included in rotations with crops (especially on sandy soils) in a form of ley rotation. Although this is undoubtedly true in terms of soil stability, it has been found (Barnes 1981a,b; Rodel et al. 1981a) that the residual effect of fertilizer applied to the ley is small and that fertilizers applied to pastures must be justified economically by the returns from the livestock that feed on those pastures.

PLANT INTRODUCTION AND SCREENING

Plant Introduction

There is no organized local herbage plant-collection program in Zimbabwe, but there has been a fair amount of a rather haphazard collection of both grasses and legumes. When an interested person saw a promising-looking legume or grass in seed, seed would be collected and forwarded to a research station. Rather more grasses than legumes have been collected in this way.

With pasture legumes, the main pathway of introduction has been through correspondence. Initially, the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Tropical Pastures in Brisbane was the main source of seed, but seed has also come from eastern and southern Africa, the USA, and, more recently, from agencies in South America. Legume introduction and screening in Zimbabwe for the period 1968-73 has been summarized by Clatworthy (1975). Climatic classifications such as those of Papadakis (1961) form a useful guide to regional sources of potentially valuable germ plasm.

Pasture Plant Screening

All introductions, both grasses and legumes, are initially grown in nurseries for observation, and it was solely on the basis of nursery performance that West (1952) produced a list of nine grasses considered to show promise for use in pastures.

Screening based only on performance in the nursery is obviously not sufficient and Barnes (1966) advocated a design in which grasses were grown in unreplicated long beds and defoliation treatments were applied at right angles across them. Strips were cut once, twice, or three times per year with a forage harvester or were left uncut, while one strip was grazed at appropriate intervals. Yields were not measured, but records were kept of such features as vigour of growth, freedom from disease, time of flowering, earliness of shooting, and persistence under defoliation. Grasses showing promise were then included in replicated cutting trials and it was on the basis of this procedure that Muguga Star grass (Cynodon nlemfuensis var. nlemfuensis), Beehive paspalum (P. plicatulum), Wintergreen paspalum (P. guenoarum) Paraguay paspalum (P. notatum), and Umtali panicum (Panicum maximum) were released to commercial agriculture. In 1970, the work on grasses and legumes was separated and screening of the two has since followed very different lines.

Grasses

Pasture work at Henderson Research Station has concentrated on pure grass stands liberally fertilized with nitrogenous fertilizer. Rodel and Boultwood (1971), in a comparison of 30 grasses, showed that the soloniferous types were more productive under frequent cutting than the tufted ones and that their yields were less affected by fluctuations in rainfall. Rodel (1970) also demonstrated that the soloniferous grasses, Star grass (C. nlemfuensis) and couch (C. dactylon), persisted better under intensive grazing than the tufted grasses Giant Rhodes grass (Chloris gayana), Ermelo weeping love grass (Eragrostis curvula), and Sabi panicum (P. maximum).

Mills (1977b) reported the results of a screening trial that was a modification of Barnes' earlier proposals. Strains of Brachiaria species, Digitaria species, Cynodon species, Eragrostis species, and Panicum species were grown in long replicated plots across which were applied two frequencies of grazing, each leaving two heights of stubble after grazing. The grasses persisted poorly and the trial was abandoned prematurely, but it had shown the shortcomings of the design as well as of the grasses. In another paper, Mills (1977a) showed that the preferences of sheep and cattle for different grasses were sufficiently dissimilar that sheep could not be used to estimate the acceptability of grasses to cattle.

P. notatum is a grass that has proved highly productive (Mills et al. 1973) but possibly of low acceptability to cattle. A number of P. notatum accessions were compared for yield and palatability at Henderson Research Station but, although some accessions significantly outyielded Paraguay paspalum and some appeared more palatable, the differences were not considered great enough for new strains to be released commercially (Mills and Boultwood 1978).

Subsequent screening trials with grasses have concentrated on Cynodon species with the aim of producing strains even better suited to local conditions than the No. 2 strain of Star grass (Mills and Boultwood 1981).

Legumes

There are two likely roles of pasture legumes in local agriculture - for the reinforcement of native grazing and for use in sown pastures. The methods of screening for these two roles are likely to be different.

Reinforcement of native grazing. The main criteria of success in this role are the ability to establish and to persist with minimum management inputs. Barnes (1966) had produced a short list of five legume species that he deemed worthy of further study. These (with the exception of Stylosanthes fruticosa, but with the addition of Listia heterophylla) were sown on disked grassland after various pretreatments and with and without a grass mulch. Dry conditions followed seeding and only S. guianensis produced an acceptable stand of seedlings (Clatworthy and Thomas 1972). This emphasized that in screening legumes for veld reinforcement the ability to establish under adverse conditions is perhaps the most important criterion and that screening should be done in conditions as similar as possible to those under which the legume is likely to be used. An example is that of Clatworthy (1980) who seeded 12 legumes in disked grassland at the Grasslands Research Station (sand) and at Henderson Research Station (clay) and applied simulated rotational grazing at different seasons for 5 years. On the sandy soil, Oxley fine-stem stylo (S. guianensis var. intermedia) was the only satisfactory legume, but on the clay soil a number of legumes grew well of which Silverleaf desmodium (D. uncinatum) was outstanding, particularly when grazed only in the dry season.

The shortcomings of cutting trials for assessing the suitability of legumes for veld reinforcement are illustrated by the results of cutting trials with a number of stylos at three sites on sandy soils. Even stylos that were known to persist under grazing died out under cutting (Clatworthy 1984a). Stylos and other legumes for veld reinforcement are now screened by sowing them on disked strips in grazed paddocks and monitoring changes in the plant population.

Sown pastures. Legume pastures sown on ploughed land are most likely to be used in some sort of ley system in which the pasture will be ploughed out after some years and the land used for arable cropping. Under these conditions the criterion of success is the ability of the legume to produce satisfactory yields of nutritious and palatable herbage, perhaps for relatively few years, and long-term persistence is not important. Cutting trials form a satisfactory method of evaluating legumes for this role, especially if combined with chemical analysis of the harvested herbage and with observations of the acceptability of the legumes to livestock. Clatworthy (1984b) found that Desmodium species (D. intortum, D. uncinatum, and, less satisfactory, D. sandwicense) were very suitable ley legumes for high rainfall areas (c. 900 mm), while Siratro (M. atropurpureum) and Archer (Macrotyloma axillare) grew well at the drier Makoholi site (650 mm) (Clatworthy 1984b).

Farming Practice

Grasses

By far the largest area of sown grass in Zimbabwe is of Katambora Rhodes grass. This has been sown not primarily for its value as a grazing grass but because it is resistant to root-knot nematode and is, therefore, a suitable grass for growing in rotation with tobacco. Because of the area involved it does, however, represent a considerable grazing resource. The grass grown most widely specifically for grazing is Star grass. This responds well to fertilizer, stands up to heavy grazing, and planting material is widely available. These two grasses have been part of the agricultural scene in Zimbabwe for many years as Katambora Rhodes grass was released in 1953 and Star grass was grown as early as 1941 (Timson 1943).

The main reason why the more recently selected grasses have not been widely grown has been because of difficulties of establishment and the fact that, being tufted grasses, they do not fill in gaps in the stand. The only seeded grasses other than Katambora to which this criticism does not apply are the E. curvula cv. Ermola (selected long ago) and the newer Umgeni. These are also grasses more chosen for their nematode resistance than for their grazing value.

Legumes

There are three pasture legumes of which seed is freely available in Zimbabwe -- Oxley fine-stem stylo, Siratro, and Silverleaf desmodium. Oxley stylo is used primarily for veld reinforcement on sandy soils, Siratro for pastures on a wide range of soils in the hotter areas, and Silverleaf desmodium for pastures on heavier soils. An unofficial survey (Wood, personal communication) suggested that there were about 6,500 ha of legume-based grazing in Zimbabwe, and this was composed almost entirely of these three cultivars.

Small amounts of seed of Archer, Beit lotononis, Cooper glycine, Townsville stylo, and Kenya white clover have been produced in the past but these cultivars have never been widely grown, and the shortage of seed of D. intortum has prevented its wider use.

Research Priorities

Grasses

Probably the project with the greatest impact would be the isolation of a strain of Rhodes grass of greater forage value than Katambora and resistant to root-knot nematode. None of the "Giant" types screened have proved nematode resistant and a breeding program attempting to cross Katambora with a Giant type may be needed.

Until now, the screening of pasture grasses has been done with nitrogen fertilizer (often at very heavy rates). There is an urgent need to select grasses that will combine with pasture legumes to form stable and productive mixtures on a range of soil types and under various climatic conditions.

Finally, there is a role for the selection of "better" strains of pasture species already used in pastures. An example of this is the Cynodon selection program in which strains have been found that outyield the currently used No. 2 strain by about 20%. It remains to test how great the effect is on animal production.

Legumes

The greatest need is to expand the range of legumes available so that cultivars can be recommended for geographical areas or for uses for which the three present cultivars are not suitable. This will entail regional screening trials with test plots grown in the areas concerned and used in the ways for which needs exist.

ESTABLISHMENT

Seed Treatment

Grasses

Several grasses that have been used in pastures in Zimbabwe have seed that is initially dormant. Smith (1966a) showed that the dormancy of freshly reaped seed of Sabi panicum could be overcome by treatment with concentrated sulphuric acid for 2-5 minutes. Nitric or hydrochloric acids did not produce a similar effect. Little work has been done with other grasses, but dormancy is known to be a problem and common advice is that seed of Panicum spp. or Paspalum spp. should not be sown for a full year after it has been reaped.

Legumes

Seed-coat impermeability to water or hand-seededness is a problem with many pasture legumes, and it can be overcome by hot water, dry heat, mechanical scarification, or treatment with concentrated sulphuric acid (Anonymous 1977, Grant and Clatworthy 1978). Mechanical scarification is convenient, and effective treatments have been defined for most of the legumes commercially grown in Zimbabwe (Seed Services, unpublished; Anonymous 1979; Grant 1979b, 1980).

Greenhouse Trials

Smith (1966a), with Sabi panicum and Giant Rhodes grass, and Grant (1975), with various legumes, have demonstrated the overriding importance of depth of sowing on the emergency of small-seeded pasture species, especially on silty soils. For maximum emergence, seed should be sown at a depth of 5-10 mm.

Grant (1975) also demonstrated that under conditions of moisture stress, shading the soil surface or covering it with a mulch increased seedling emergence, but the mulch reduced emergence when the soil was kept moist.

Field Studies

Veld Reinforcement

Up to the present, all work on veld reinforcement has been done with legumes and no attempts have been made to introduce pasture grasses into native grassland. It has already been emphasized that on sandy soils Stylosanthes spp. are virtually the only legumes to establish satisfactorily following rudimentary seedbed preparation and all recent veld reinforcement trials at Grasslands Research Station have been done with Oxley fine-stem stylo.

Establishment of fine-stem stylo was found to increase when there was a degree of soil disturbance before sowing. Thus, three diskings before sowing were found to be better than one, and burning immediately before disking was found to be beneficial, possibly because it allowed greater soil penetration by the discs. Rolling to compact the seedbed was also considered advantageous, particularly if the plots were rolled before drilling or after broadcasting the seed (Grant 1976).

Open Seeding

Smith (1966a,b) showed that mulching with chopped hay greatly increased emergence and subsequent yields of Sabi panicum and of Katambora and Giant Rhodes grasses on a soil that is liable to form an impenetrable surface crust. Smith's work also emphasized the effect of weeds in reducing the establishment of pasture grasses and he remarked that a relatively late time of sowing (January to early February) resulted in fewer weeds and better pasture establishment.

Grant (1976) demonstrated the benefits of a mulch in the establishment of pasture legumes on sandy soil and he, too, emphasized the importance of competition from weeds in reducing establishment. Establishment was improved by getting rid of the first flush of weeds before sowing -- if this were done mechanically, drag harrowing was better than disc harrowing or using a rotary weeder. The best results were obtained where the soil was firmed with a Cambridge roller or with a tractor wheel before seeding and where the seed was covered either with a flat roller or by light brushing or raking (Grant 1979a).

Weeds can also be controlled, and legume establishment increased, by the use of herbicides. Trifluralin controlled grass weeds but damaged legume seedlings at all except very low rates. Eptam provided satisfactory control of grass weeds and did not harm the legumes but neither did it affect dicotyledonous weeds (Grant 1978). Later work has shown that Alachlor and Metolachlor are also suitable for weed control in pasture legumes and that Alachlor reduced dicotyledonous weeds (Irvine 1984). However, the cost of herbicides is high and their use is probably justified only in legume crops that will be used for seed production, as the return from grazed pastures is likely to be too low to cover the cost.

Underseeding

Addison et al. (1959b,c) successfully underseeded Giant Rhodes grass and Horse Marmalade (Desodium discolor) between the rows of a Jack bean (Canavalia ensiformis) crop and there seems little doubt that other legumes could be used as cover crops. Maize, however, is the crop into which pastures are most commonly underseeded and Addison et al. (1959a) showed that Giant Rhodes grass could be undersown successfully after early flushes of weeds had been cultivated. In both that trial and in later work (Anonymous 1971), the stand of grass and resulting herbage yields were greater where the stand of maize had been reduced, either by wider row spacing or by sparser planting in the row, but this led to reduced maize yields. It was subsequently shown that the earlier the grass was underseeded into the maize the greater was the yield of grass the subsequent season (Anonymous 1973a). Weed control in these early underseeded crops could be achieved by the use of the herbicide Atrazine. Unfortunately, it has never been tested whether early underseeding will allow grasses to be established successfully in maize crops grown at normal population densities.

Atrazine is toxic to dicotyledons and so cannot be used on maize crops into which legumes are to be underseeded (Anonymous 1972). Eptam is suitable for this role but has the disadvantage that it is ineffective against dicotyledonous weeds (Grant and Clatworthy 1978), but these are usually less of a problem than grass weeds. Alochlor may prove a very suitable herbicide for use in underseeding. When underseeding legumes there appears to be no need to reduce the maize stand as legume establishment was not affected by maize population over the range of 30,000-50,000 plants ha^{-1} (Grant 1980).

Farming Practice

Grasses

As already emphasized, most grass seed is sown in rotation with tobacco. The common method of establishment is to plough in the tobacco stalks as soon as reaping is completed, roll with a Cambridge roller, broadcast the seed and then roll again, at right angles to the original rolling if possible. In most years, this results in weed-free and dense stands of grass that can be grazed early in the following rainy season. This method is particularly successful with Love grass and Katambora Rhodes grass.

The runner grasses, such as Star grass, are commonly established by digging rooted runners and then planting them in holes chopped by hoe, commonly at a spacing of 1 x 1 m. As wages increase, hand planting in this way will become increasingly expensive.

Legumes

Pasture legumes are relatively new in Zimbabwe and it is difficult to generalize about their use. Several farmers have made up implements that prepare loosened soil, apply fertilizer and disc it in, apply seed and cover it all in one pass of the tractor. These have been used mainly for veld improvement but sometimes also for sowing legumes on ploughed land or into existing grass pastures. Underseeding as a means of establishing legume-based pastures is becoming popular, although it is less effective in dry seasons such as those we have experienced recently.

Research Priorities

Grasses

To a great extent the methods of establishing pasture grasses, especially in rotation with tobacco, have become fixed by experience and it is largely a function of research to select grasses that will establish satisfactorily using those methods. With the increasing cost of hand labour, the cost of planting grasses from runners is escalating. There is a need to develop ways of mechanizing the planting process.

Legumes

Probably the greatest long-term need is for inexpensive methods of seeding legumes into native grassland over large areas. Research will involve combinations of selecting species or strains of legumes that can establish under adverse conditions and the definition of techniques that will make the conditions as little adverse as possible. Past research allows fairly definite recommendations to be made concerning the establishment of legume-based pastures on ploughed land.

MANAGEMENT

Fertilization

Grasses

Results obtained before 1964 were summarized by Weinmann (1964). The main effort in fertilizing grasses has been on levels of nitrogen application, and fertilization with other plant nutrients has received scant attention. Addison (1956) demonstrated a marked interaction between the nitrogen and superphosphate requirements of Napier fodder (Pennisetum purpureum) under cutting: with heavy dressings of nitrogen, heavy dressings of superphosphate were also necessary if maximum yields were to be obtained. Since then there has been little work on the effects of superphosphate on grass yields and none under grazing. Superphosphate applications have been based on the results of soil analysis and have tended to be generous. With the recent marked increases in the price of superphosphate, work on the superphosphate requirements of grazed pastures appears to be justified. Responses to lime by grasses have generally been small and sometimes even negative, but Addison (1958) showed that after 2 years of applying the acidifying nitrogenous fertilizer ammonium sulphate, Napier fodder benefited from lime application. When grass pastures have been used in a ley situation the general recommendation has been to apply lime when the grass is ploughed out but more frequent small dressings to maintain soil pH at a higher level may be better. Rodel (1979), working with Star grass on a granite sand, recorded increased herbage yields from sulphur application, but not from applications of boron, zinc, or magnesium.

The main response by grasses has been to applications of nitrogen and in a number of experiments dry matter (DM) and crude protein (CP) yields were shown to increase roughly linearly with nitrogen applications of up to 200 kg N/ha. There is generally little response to nitrogen during the 1st year of a pasture, when there is considerable free nitrogen in the soil, but marked responses by older pastures. In one experiment at the Grasslands Research Station, nitrogen applications of up to 470 kg N/ha were applied to Star grass and resulted in yields of 19,550 kg DM and 2,740 kg CP/ha in three cuts (Weinmann 1964).

Clatworthy (1967) demonstrated that an old Giant Rhodes grass pasture on red soil at the Henderson Research Station could produce high yields if fertilized with 450 kg N/ha and this led to the work of Rodel and Mills already mentioned in the section on screening. From work with five grasses, Rodel (1979) showed that on a sandy soil maximum herbage yields were obtained with 601 kg N/ha and on a clay soil with 665 kg N/ha. However, because of the decrease in response as nitrogen level increased, he suggested that in practice nitrogen applications on sands should not exceed 225 kg N/ha. On heavier soils, heavier nitrogen dressings are justified, and Rodel suggested 350 kg N/ha. Under irrigation, the growing season of the pasture is considerably lengthened and the demand for nitrogen is likely to be increased. As a result of their experiments with two grasses on two soil types, Rodel et al. (1981) recommended 650 kg N/ha as the optimum nitrogen rate for irrigated pastures.

Legumes

Corby (1959) summarized the results of trials with a number of legumes at the Grasslands Research Station by saying that there was evidence of responses in certain cases to lime and to superphosphate, especially when these were worked deeply into the soil. There was also evidence of a response to boron or iodine by lucerne (later unpublished work on the Grasslands Research Station showed marked responses by irrigated lucerne to boron, especially during the cold period of the year). At that time, there was no local source of inoculants and responses by legumes that did not nodulate effectively with soil Rhizobium strains could have been limited by N deficiency.

The effect of nitrogenous fertilizers suppressing the lgeumes in grass-legume mixtures is well illustrated by the results of Clatworthy (1970). Six creeping grasses were grown alone or with Lotononis bainesii or with Kenya white clover (T. semipilosum) with nitrogen applications of 0, 112, and 224 kg N/ha/year. There was a marked effect on the legumes in the absence of nitrogen, a small response with 112 kg N/ha and none with 224 kg N/ha, at which level the legumes had virtually been excluded from the mixture.

There has been little work on the fertilizer requirements of subtropical pasture legumes, although unpublished results on the Grasslands Research Station suggested that L. bainesii persisted better on plots to which gypsum had been applied. S. guianensis was shown to respond to applications of superphosphate on both sandy and clay soils but at the highest level of application there was a marked decrease in yield in the second harvest year (Anonymous 1973b).

A similar effect was recorded by Grant and Tanner in a trial in which a range of superphosphate applications up to very heavy rates was applied to Siratro and Oxley stylo at two sites on sandy soil and to Siratro and Silverleaf desmodium at one site on a clay. The stylo initially showed marked increases in yield with increasing superphosphate rates, but then (particularly in one replication at the Grasslands Research Station) yields dropped markedly at high applications (Grant and Tanner 1983). There are indications that induced zinc deficiency may account for this decrease in yield (Grant, P.J., personal communication). The other legumes were not affected.

Grant and Tanner (1983) also demonstrated an apparent interaction between dolomitic limestone and superphosphate applications on sandy soil. Superphosphate at 200 kg/ha increased legume yields with lime applications of 500-2,000 kg/ha but decreased them with 4,000 kg lime/ha. This interaction did not occur on a red soil.

Defoliation Management

Grasses

Numerous cutting trials have been carried out to measure the effect of frequency of defoliation on yield and quality of grass herbage. Almost always, the greatest DM yield was obtained with one or two cuts per season but maximum CP yields were obtained with a greater number of harvests. This type of trial has little direct relevance to the grazing situation.

Rodel (1979) described a series of trials in which the effect on No. 2 Star grass of various defoliation treatments was measured under grazing. In the first, three levels of nitrogen (170, 340, and 510 kg N/ha) were applied and the grass was grazed whenever it was 10, 20, or 30 cm tall. After grazing, each plot was cut back to leave a stubble 5 cm high. Quadrats were cut before each grazing to measure herbage yield. The greatest yield was obtained with the most frequent grazing and with that treatment yields in the 2nd year of the trial increased to the highest level of nitrogen application.

With less-frequent grazing the response to nitrogen was less marked. Basal cover measurements showed that there was progressively less basal cover due to weeds, and more due to Star grass, as nitrogen level increased. The basal cover of Star grass also increased (but not as markedly) progressively as grazing height decreased.

Rodel and Boultwood (1981) also measured the effect of the residual stubble height on yields of Star grass that were grazed at 15-day intervals and fertilized with 510 kg N/ha. Stubble heights of 5, 10, and 15 cm were left after each grazing, and grazing only started when there was a set amount of herbage above that height. Yields increased with decreasing stubble height. In this trial, as in the one above, effects of the treatments were greater in the 2nd year than in the 1st, suggesting that the sward was in some way conditioned by the treatment. That both frequent grazing and a short stubble after grazing appeared to increase yields of Star grass suggests that continuous grazing may be a very suitable way to use these pastures.

Legumes

A series of trials was conducted by Mufandaedza to measure the effects of various cutting treatments on the yields of various grasses and legumes grown separately or in mixtures. In the first, plants of Heteropogon contortus, Hyparrhenia filipendula, or of three strains of S. guianensis were grown in pots in the greenhouse and cut at different frequencies and heights. The results showed in particular that Oxley fine-stem stylo is extremely tolerant of frequent and short defoliation (Mufandaedza 196a,b).

In a subsequent experiment, Mufandaedza (1979) established stands of H. filipendula and grew the grass on its own or mixed with Oxley stylo or with Siratro. Plots were cut at intervals of 2, 4, 8, or 16 weeks leaving a stubble of 4 or 10 cm. Addition of the legume was shown to increase DM and, especially, CP yields after the first season. Frequent and close defoliation favoured the Oxley stylo, which was shaded when the grass was allowed to grow tall. On the other hand, Siratro, because of its twining habit, climbed up the grass and thrived under infrequent cutting but was greatly reduced when it was cut frequently.

Farming Practice

Grasses

As stated several times, the main areas of sown grass are those in rotation with tobacco. These are generally not fertilized with nitrogen, are of low productivity and are managed in a manner very similar to that recommended for native grassland. As long as the requirements of the tobacco crop take precedence over all other activities on the farm, this situation is not likely to change greatly. Fertilized grass pastures are most commonly used for dairy production where they are usually grazed under some form of rotational system with a paddock grazed for 1 or 2 days and then rested for perhaps 3 weeks.

Legumes

Most farmers who have established pasture legumes have done so largely out of interest and are prepared to fertilize them generously. Superphosphate is the fertilizer most commonly used, although there have been reports of apparent responses to lime, especially on vlei soils.

Areas of native grassland reinforced with fine-stem stylo have generally been managed in a similar way to that recommended for unimproved veld -- rotational grazing with a period of stay not longer than 2 weeks and a rest period of at least 5 weeks. As such small areas are involved and farmers are still feeling their way, it is impossible to generalize about the management of pastures sown on arable land.

Research Priorities

Grasses

One aspect that has already been mentioned is the need to examine the superphosphate requirement of grazed pastures. Current recommendations tend to be generous and with the recent increases in the cost of superphosphate, there may be room for economies.

As a result of the work of Rodel, we have a very clear picture of the effects of various management treatments on fertilized Star grass pastures. There seems to be no real advantage in complicated rotational grazing systems, and continuous grazing during the rainy season is the most efficient way of using Star grass. Until new grass cultivars become available to which current recommendations do not seem to apply, there is little need to continue detailed work on the management of grasses.

Legumes

As with grass pastures, there is a need to establish minimum maintenance fertilizer levels for grazed legume-based pastures. There is also a need to determine the effect of various defoliation treatments on mixtures of pasture grasses and legumes along similar lines to the work of Mufandaedza, which was relevant to legume-reinforced veld. Although the results of trials of this type are not directly applicable to the grazing situation they form a useful guide in deciding management principles. These principles will then obviously need to be confirmed under grazing.

PRODUCTIVITY AND UTILIZATION

Grasses

Following Rodel's series of experiments on grazing management strategies for Star grass pastures, he conducted a number of grazing experiments to measure the animal productivity of these pastures and the effects of management variables on it. The results of these trials were expressed in terms of increase of carcass mass, to eliminate differences due to gut fill, and the period on pastures was regarded as part of a system of production with half of the steers being subsequently pen-finished to slaughter mass.

In the first trial on Star grass fertilized with 350 kg N/ha, steers were set-stocked at 12 steers/ha or rotationally grazed through 15 paddocks at 12 and 20 steers/ha. There was an additional treatment at 20 steers/ha in which the steers were fed 3 kg/head/day of a concentrate feed containing 13% CP. Carcass mass gains for the four treatments were 35.2, 33.8, 17.8, and 63.0 kg/head, respectively, or 422, 406, 356, and 1,260 kg/ha (Rodel 1979).

In 1973-74 (which was a very wet season), steers were carried on Star grass pasture fertilized with a constant 350 kg N/ha in a 15-paddock rotational system at stocking rates of 12.0, 14.7, 17.3, and 20.0 steers/ha (Rodel 1979). The experiment was repeated in 1974-75 except that nitrogenous fertilizer was applied at the rate of 25 kg N/steer (Rodel et al. 1981). The carcass mass gains of the steers in these two seasons are presented in Table 1.

From Table 1 it can be seen that gain/ha was affected both by stocking rate and by nitrogen rate, and Parkin and Boultwood (1981) presented the results of a trial in which steers grazed Star grass pastures fertilized with 100, 200, 300, and 400 kg N/ha at four stocking rates for each N level. Overall, stocking rates ranged from 5 to 14 steers/ha, and the trial ran for 4 years. Curvilinear regressions were derived both for the stocking rates within each N level and also for the mean effects of each N level. Carcass mass gains of up to 550 kg/ha were recorded on pastures fertilized with 400 kg N/ha.

Table 1. Carcass mass gains (kg) of yearling steers grazed at four stocking rates on Star grass pastures fertilized with 350 kg N/ha (1973-74) or with 25 kg N/steer (1974-75).

	1973-74 350 kg N/ha		1974-75 25 kg N/steer	
	Steer	ha	Steer	ha
Stocking rate -- steers/ha				
12.0	22	264	34	408
14.7	15	221	37	544
17.3	4	138	30	519
20.0	-4	-80	25	500
Calculated optimum stocking rate	9.5 steers/ha		16.9 steers/ha	
Gain at this stocking rate	282 kg/ha		558 kg/ha	

In this trial, part of the differences in how much the cattle gained from year to year could be ascribed to differences in their condition when they were put on to the grazing. As an extension of this, weaner steers were overwintered on native grazing with different levels of protein supplement to produce marked differences in body condition at the end of the dry season. They were then run on Star grass pastures fertilized with 350 kg N/ha for the growing season at stocking rates of 7, 9, 11, and 13 steers/ha. Gains per head on the pasture were decreased by increased stocking rate and also by increased protein supplement during the dry season. Steers fed 1,400 g cotton seed meal/head/day were 40 kg/head heavier than the unfed controls at the start of the pasture phase, but only 25 kg/head heavier by its end (Parkin et al. 1981). These results provide clear evidence of the effects of compensatory growth.

In all the trials on dryland pastures, the results were affected by differences in rainfall from year to year and also by dry spells during the rainy season.

To reduce these differences as much as possible, a series of trials on the effects of grazing management on Star grass pastures was carried out under irrigation (Rodel et al. 1984). Eight grazing treatments were used in which the number of paddocks per herd ranged from 1 to 18 and the period of stay in each paddock differed between systems. In the 1st year, there appeared to be a slight benefit from the 18 paddock systems with periods of stay of 1 or 2 days, but by the final year the treatments with fewest paddocks (continuous grazing, 6 days graze; 6 days rest and 6 days graze; 12 days rest) resulted in the greatest gains. However, measurements of the available herbage at intervals during the growing season showed that there was always more herbage available in the multipaddock systems. In an attempt to utilize this extra herbage, stocking rates were increased each year, being 12 steers/ha in the 1st year, 15 steers/ha in the 2nd, and 18 steers/ha in the 3rd, but this had little effect. The pastures were fertilized with 640 kg N/ha and carcass mass gains over the 3 years averaged 940 kg/ha.

In that trial, the effects of stocking rate were confounded with the effects of the different seasons. In a later trial, on the same pasture, stocking rates of 15, 18, and 21 steers/ha were compared under continuous grazing and 6-paddock systems with grazing periods of 2, 4, and 6 days. In both seasons, the greatest carcass mass gain/ha was obtained from continuous grazing at the lowest stocking rate and this averaged 1,000 kg/ha (Parkin and Price 1980). There was no evidence that rotational grazing was preferable at heavy stocking rates, as has often been suggested.

Legumes

Reinforced veld. On the Grasslands Research Station, half of a 24-ha block of reverted land dominated by *H. filipendula* was seeded with Oxley stylo in disked strips and half was left as a control. For 6 years the two areas were grazed by weaners purchased in June and removed the following June for pen finishing. During the dry season, steers on reinforced grazing maintained livemass, whereas those on the control lost on average 20 kg; both groups gained the same amount during the period November-February but between them and June steers on reinforced grazing gained 20 kg more than the controls. There was, thus, a 40-kg increase in gain per head during the year as a result of reinforcement and, as the stocking rate was about 20% greater on the reinforced area, gains per ha were increased 61% by reinforcement (Clatworthy and Holland 1979).

Observations on the cattle grazing in this trial showed that they started to select stylo plants from about mid-January, although they only appeared to benefit from the stylo from early March onward (Mufandaedza 1977). A treatment was, therefore, included in which the reinforced veld was rested from January to April in an attempt to allow a build-up of stylo herbage. Unfortunately, the Hyparrhenia was growing rapidly during this period and tended to shade the low-growing stylo so that effects on animal production were disappointing (Clatworthy and Muyotcha 1980).

Silverleaf desmodium establishes well on disked veld at the Henderson Research Station, and the effect of reinforcement with it on dry-season performance of beef weaners was studied over 5 years. The Silverleaf desmodium was largely defoliated by frosts, and steers in both treatments lost livemass over the dry season, although they lost less on the plots containing Silverleaf desmodium (Clatworthy 1984c). Results of resting reinforced veld for grazing in autumn or the dry season have, therefore, proved disappointing and reinforced veld is probably best used for grazing year round or during the growing season when its nutritive value is at its highest.

Dryland pastures. Probably the first time in Zimbabwe that animal production was measured off a legume-based pasture as the sole source of feed was when the results were presented by Clatworthy and Boultwood (1974). A 2.46 ha area of Desmodium intortum with varying amounts of Star grass on the Henderson Research Station was fenced into four paddocks that were grazed in rotation by three steers. Over a 16-month period, these gained an average of 304 kg and similar results were obtained over the next 2 years, with a pattern of rapid livemass gain during the rainy season and near-maintenance during the dry season. During the period of grazing, the proportion of legume in the pasture decreased steadily.

At the Grasslands Research Station, a 6.5-ha field was sown with a mixture of Siratro, Silverleaf desmodium, Oxley stylo and lotonis, and grazed year-round at a stocking rate as similar as possible to that of the reinforced veld in the trial already referred to. Because of the greater proportion of legume in the sown pasture, gains on it were considerably greater than on the reinforced veld (Clatworthy and Muyotcha 1980). No grass had been sown in the pasture and, possibly because of this, it became invaded by weeds, especially *Tagetes minuta*. To test the effect of stocking rate on the weeds and on animal production, the pasture was subdivided to give stocking rates of 0.93 and 1.85 steers/ha. Livemass gains per hectare were greater at the high stocking rate but, because of the poorer carcass quality of these animals, monetary gain was greater at the low-stocking rate.

At both the Grasslands and the Henderson Research Stations, similar trials have been conducted on Star grass/Silverleaf desmodium pastures. The pastures were grazed during the growing season only at four stocking rates and with continuous and rotational grazing (Ackerman and Boultwood 1983; Clatworthy and Muyotcha 1983). Livemass gains of up to 1 kg/steer/day were recorded at the lighter stocking rates, decreasing as stocking rate increased. Silverleaf desmodium is particularly well adapted to conditions at the Henderson Research Station, and the calculated maximum livemass gain there (606 kg/ha at 5.85 steers/ha) was considerably greater than at the Grasslands Research Station (431 kg/ha at 3.84 steers/ha). At the Grasslands Research Station, the proportion of Silverleaf desmodium in the pasture decreased markedly with time, but this has been much less the case at Henderson.

Irrigated pastures. Irrigating grass-legume pastures not only results in a much longer growing season but allows different species of legumes to be grown. Clovers (*Trifolium* species.) persist poorly if at all on dryland in most parts of Zimbabwe but do well under irrigation. Clatworthy (1977) showed that under irrigation grass plus Kenya white clover pastures were about as productive as grass pastures fertilized with 450 kg N/ha/year. A larger area (5.5 ha) of Kikuyu grass and Kenya white clover was established and the effects of stocking rate and of grazing procedure on both steer gains and pasture composition were determined. During a grazing period from mid-October to June, carcass mass gains of up to 1,000 kg/ha have been recorded, (Clatworthy and Price, unpublished) and these are similar to those from irrigated Star grass pastures fertilized with 640 kg N/ha. There has been little effect of the management procedures on pasture composition. The main problem experienced on these pastures has been that of bloat, but this can be largely prevented by feeding prophylactic agents. The irrigated Kikuyu grass/Kenya white clover pastures have been used only for beef steers to date, but their main role in farming practice is likely to be for dairy production.

Farming Practice and Research Needs

Few data are available for the on-farm productivity of pastures in Zimbabwe, either nitrogen-fertilized grass or grass-legume pastures. One difficulty of obtaining these data is that pastures form only a part of the feed reserves available on any farm, where native grassland and crop residues have to be integrated to best advantage. The results of Parkin et al. (1981) are an illustration of how practices applied in one part of the production cycle can affect results obtained in another. The paper by Barnes et al. (1973) emphasizes the massive increases in productivity that are possible if all the fodder resources of the farm are fully utilized.

For these reasons, it is important that research on livestock production from pastures be seen in the context of a production system as a whole. This has already been embodied in such work as that of Rodel and Parking already quoted in Grant et al. (1983) and Grant and Golding (1983). In defining the systems to be applied, there is a need for flexibility to allow for changes in costs of inputs or in market requirements.

One aspect of potential importance that requires research is the use of grass-legume pastures for dairy production. Until now, all the research has been with beef cattle, although several commercial dairy farmers are using pasture legumes with apparent success, and they could have a useful role to play in small-scale dairy production.

SEED PRODUCTION

Very little research has been done in Zimbabwe on seed production of pasture species. The only project has been that of Irvine (1984) on Silverleaf desmodium. He showed that the main factor limiting seed production of this legume was predation of the pods by insect larvae, especially Heliothus armigera, and that scouting for this pest and spraying when an infestation was observed resulted in greatly increased seed yields. As hand-reaping seed of Silverleaf desmodium is laborious, he defined cutting or rolling treatments that resulted in a shorter and more uniform height of seeding and so facilitated mechanical harvesting.

Farm Practice

Until recently, nearly all the pasture seed grown in Zimbabwe was produced by members of the Zimbabwe Pasture Seed Growers' Association and sold through their agents. The history of this association is summarized by Davis and Hanssen (1972). Seed is grown both for the internal market and for export, the main export being Katambora Rhodes grass.

Initially, all seed was reaped by hand, but more and more of the grass seed is now combined, as is Silverleaf desmodium. Siratro and Oxley stylo are reaped by hand, usually by casual labourers paid per kilogram of clean seed produced. These two types of seed, in particular, could form useful cash sources for peasant farmers.

Research Needs

There is a marked difference in opinion between research workers and seed growers as to the main research needs of the seed industry. The research staff see as the main priority the need to produce a wider range of seeds of pasture cultivars; the seed producers emphasize the need for greater seed yields of the cultivars they are already growing.

The former is closely linked to the pasture plant screening program, and it is axiomatic that in selecting pasture cultivars more attention than in the past should be given to their seeding ability and the suitability of the seed for mechanical harvesting. As long as Katambora Rhodes grass remains the main, and virtually the only, grass seed produced -- not for its pasture value but because of its role in suppressing nematodes in the tobacco rotation -- it is doubtful whether the resources of the Pasture Research team should be channeled toward increasing yields of grass seed.

SMALL-SCALE AGRICULTURE

As yet there has been little use of pastures, either of nitrogen-fertilized grass or of legumes, in small-scale farming. What little there is, has usually been due to the enthusiasm of individual extension workers who have convinced farmers of the benefits they can obtain.

Several small-scale farmers have established small patches of pasture legumes on unused portions of their arable area. These are protected from grazing during the growing season and may offer a source of cash income if seed is reaped from them. The extent to which the cattle of the landholders benefit from these legumes as a source of winter feed depends on whether they have the resources to cut and store hay or have the fencing to exclude other cattle. Communal grazing is a disincentive to improvements intended to increase livestock production. On the other hand, at least one farmer regarded his legume patch as a fertility improver in his rotation. When asked why he did not reserve the grazing for his own cattle he pointed out that his cattle alone could not have produced all the dung that had been dropped on the land! Small-scale dairy production offers one way of integrating pastures into the farming system and increasing cash income of the farmers.

The introduction of legumes into grazing areas in the communal lands appears to offer attractive possibilities for increasing the carrying capacity of these areas. However, the first priority ought surely to be to establish a degree of control of the grazing in these areas so that the basic principles can be applied. Only when this has been done successfully is the time ripe for further improvement. Nonetheless, it is important that research on species selection and methods of establishment and management suited to the conditions be undertaken in advance so that when the time is ripe firm recommendations can be made.

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HIGHLIGHTS OF PASTURE RESEARCH IN MALAWI: 1975-84

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Abstract *This paper reviews highlights of pasture research in Malawi for the period covering the late 70s to the early 80s on species and cultivar introduction and evaluation, simple grass-legume mixtures, and animal production potential of planted improved pastures and that of legume reinforced natural grasslands. A statement of priorities for future research areas is also presented.*

The period during the late 60s and early 70s saw the beginnings of organized pasture and fodder-crops research in Malawi. The main emphasis was placed on germ-plasm introduction and evaluation in small plots for adaptation to local conditions. Alternative tropical forage grasses to Chloris gayana, the established commercial species, were sought to fit into grazing and stall-feeding enterprises. As a result of this work, a number of species and cultivars belonging to the genera Panicum, Chloris, Cynodon, and Cenchrus have shown good potential for forage.

The increasingly high costs of inorganic nitrogenous fertilizers have prompted a search for leguminous forage species in the genera Stylosanthes, Macroptilium, Macrotyloma, Neonotonia, Centrosema, Desmodium, and Leucaena as a source of cheap biologically fixed nitrogen. There is an ongoing evaluation program for all the germ-plasm accumulated to date. The evaluation program is geared toward fitting forage grasses and legumes to stall-feeding and grazing enterprises for beef and dairy production.

EVALUATION OF AVAILABLE GERM PLASM

Alternative Species to Rhodes Grass

Attempts to seek alternative grazing and stall feeding grasses to Rhodes grass (C. gayana) were initiated in the late 60s. Before this, Rhodes grass was and has continued to be the major commercialized species. Comparative studies to screen different alternative species to Rhodes grass indicated the potential of Panicum maximum cv. Ntchisi panic grass, a local ecotype collected from the wild and other ecotypes, and Cenchrus ciliaris (Table 1). Being a more robust panic grass, it was recommended for "cut and carry" purposes along with Pennisetum purpureum strains such as Gold Coast and Cameroons.

Evaluation of Rhodes Grass Strains

Since the early 50s there have been two documented Rhodes grass strains in Malawi (Dzowela 1984). These are Katambora from Zambia via Zimbabwe and Giant whose entry into Malawi from Tanzania was preceded by two strains, Teso and Mpwapwa, both of which were morphologically similar to Giant (Anonymous 1955, 1956, 1957, 1958, 1959, 1960, 1961). Katambora is a diploid that gained popularity because of its ability to suppress the nematode Meloidogyne javanica in cropping rotations in which tobacco is included, in spite of its relatively low-forage productivity. During the 1977/78 and 1979/80 period, an attempt was made to evaluate elite Rhodes grass cultivars in commercial use in the Central and Eastern African region to identify superior material for forage production over the conventional Katambora and Giant cultivars. Table 2 shows the forage and total crude protein (CP) productivity potential of the materials tested.

In all the years under discussion, the largest amount of forage and CP were produced by Pokot followed by Mbarara and Tanzanian local and then masaba. The latter, however, showed a good regrowth potential under proper cutting management (Dzowela 1984). Both Katambora and Giant, the two naturalized cultivars in Malawi, were inferior in both these respects. Katambora, the only diploid material in the group, produced the least amounts of forage and CP.

Table 1. Comparative forage productivity potential of different grass species and cultivars.

Cultivar	Total DM[a] production (Mt/ha)[c]	Total CP[b] production (Mt/ha)	Digestibility percentage of DM
Ntchisi panic grass	9.3	1.20	62
Hamil panic grass	6.6	0.81	61
Gatton panic grass	5.9	0.74	64
Common panic grass	6.2	0.74	63
Coloured panic grass	6.5	0.80	65
Cononaio panic grass	5.8	0.73	63
Rhodes grass	5.3	0.63	60
Sabi grass	5.0	0.64	61
Bambatsi-coloured panic grass	4.0	0.50	62
Biloela buffel grass	6.2	0.71	-
American buffel grass	4.6	0.57	-
Gayndah buffel grass	4.3	0.50	-

[a] DM = dry matter.
[b] CP = crude protein.
[c] MT = metric tonnes.

Table 2. Forage dry matter (DM) and crude protein yields (CP) of elite Rhodes grass cultivars from the Central and Eastern Africa region.

	Forage DM (Mt/ha)				CP yields (Mt/ha)			
Cultivar	1977/78	1978/79	1979/80	Mean	1977/78	1978/79	1979/80	Mean
Katambora, ex-Zimbabwe	8.52	9.85	9.43	9.27	0.69	0.81	0.69	0.73
Giant, ex-Kenya	9.62	12.21	15.78	12.60	0.85	1.07	0.73	0.88
Masaba, ex-Kenya	10.68	16.10	17.69	14.82	0.75	1.12	0.87	0.91
Pokot, ex-Kenya	12.20	17.71	18.20	16.04	0.74	1.39	0.95	1.03
Mbarara, ex-Udganda	11.19	14.90	17.75	14.61	0.65	1.34	0.87	0.95
Tanzania, local	12.88	15.31	16.93	14.93	0.85	1.09	0.87	0.94
Mean	10.88	14.22	15.91	13.71	0.74	1.14	0.83	0.91
Standard error	±1.97[a]	±1.03[a]	±1.23[a]	-	±0.07[b]	+0.05[a]	±0.02[a]	
Coefficient of variation (%)	26.6	10.2	10.9	-	13.6	8.4	5.4	

[a] Statistically significant at P = 0.05.
[b] Not significant.

Because Rhodes grass is an important grass in rotations involving tobacco in Malawi, it is necessary that the forage grass, apart from being easy to eradicate when cropping is anticipated (Booman 1977), suppress the nematode populations of Meloidogyne sp. in the soil. Table 3 shows the types of concentrations of nematodes harboured in the soil around the roots of the elite Rhodes grass cultivars tested.

The analysis showed no evidence of the presence of nematodes in the roots. It only showed the presence of nematodes in soil around the roots; notably the presence of Pratylenchus sp. in Pokot, Masaba, and Tanzanian Local. This nematode does attack tobacco and predisposes the plant to other pathogens such as Fusarium (Saka, personal communication). The other nematodes recorded do not pose a serious threat to the tobacco industry yet, but this fact must be considered and caution must be exercised when recommending some of the new cultivars. Presently, Masaba, because of its seeding qualities and good regrowth attributes, is being produced by the National Seed Company of Malawi.

Evaluation of Buffel Grass Cultivars

Between 1971 and 1975, buffel grass evaluation work (Anonymous 1975) indicated the superiority of this species in terms of forage and CP productivity and persistence over Rhodes grass. This evaluation considered the added advantage that unlike other alternative species, such as Panicum coloratum, cv Bushman mine and Cynodon nlemfuensis, buffel grass produces viable seed. After 1975, three elite cultivars of buffel grass were evaluated in two distinct agroecological zones: Chitala at 600 m altitude representing the low to medium rainfall (<850 mm) Lakeshore and Shire River Valley, and Chitedze at 1,100 m altitude representing the medium plateau areas that receive rainfall between 850 and 1,200 mm. The cultivars were evaluated in response to varying nitrogen (0, 40, and 80 kg N/ha) and phosphate (0, 38, and 76 kg P_2O_5/ha) fertilization rates. Attempts were also made to find suitable compatible tropical legumes at both sites. Data derived from this study are presented in Tables 4, 5, and 6.

At the Chitedze site, Biloela produced the largest amounts of forage followed by the morphologically

Table 3. Nematode recoveries from soil samples collected from the swards of elite Rhodes grass cultivars.

Rhodes grass cultivar	Replicate no.	Nematode identification	Concentration/ litre of soil
Katambora	I	No parasitic nematode	-
Katambora	II	No parasitic nematode	-
Giant	I	No parasitic nematode	-
Giant	II	No parasitic nematode	-
Masaba	I	*Scutellonema* sp.	600
		Pratylenchus sp.	1000
Masaba	II	*Tylenchorhynchus* sp.	200
Pokot	I	*Pratylenchus* sp.	200
Pokot	II	*Tylenchorhynchus* sp.	600
Mbarara	I	*Scutellonema* sp.	1600
Mbarara	II	*Scutellonema* sp.	200
Tanzanian local	I	*Scutellonema* sp.	4000
Tanzanian local	II	No parasitic nematode	-

Table 4. Forage dry matter (DM) yield (MT/ha) and total crude protein (CP) at Chitedze (MT/ha) for the years 1977/78, 1978/79, and 1979/80.

Treatments	1977/78 cultivars			1978/79 cultivars			1979/80 cultivars		
	Biloela	American	Molopo	Biloela	American	Molopo	Biloela	American	Molopo
Forage DM yield									
N-rates (kg/ha)									
0	3.9	3.9	4.1	9.2	9.3	9.3	6.5	7.0	8.0
40	6.5	3.9	4.7	10.1	9.4	10.5	10.3	7.5	9.6
80	5.9	4.7	4.4	11.7	11.6	11.4	12.7	8.6	10.3
P_2O_5 rates (kg/ha)									
0	4.9	2.7	4.2	10.2	9.0	10.0	10.3	8.2	8.9
38	5.3	4.5	3.7	10.9	10.1	11.1	10.3	7.7	9.7
76	6.2	4.7	5.2	9.9	11.1	10.1	8.8	7.2	9.3
Cultivar									
Mean	5.5	3.9	4.4	10.4	10.1	10.4	9.8	7.7	9.3
Standard error		±1.3[a]			±0.16[b]			±0.25[a]	
N-rates (kg/ha)	0	40	80	0	40	80	0	40	80
Mean	3.7	5.0	5.0	9.3	10.0	11.5	7.2	9.1	10.5
Standard error		±0.27[a]			±0.32[a]			±0.43[a]	
P_2O_5 rates (kg/ha)	0	38	76	0	38	76	0	38	76
Mean	3.9	5.0	5.4	9.8	10.7	10.4	9.1	9.3	8.4
Standard error		±0.36[b]			±0.41[b]			±0.62[b]	

(continued)

Table 4. Concluded.

Treatments	1977/78 cultivars			1978/79 cultivars			1979/80 cultivars		
	Biloela	American	Molopo	Biloela	American	Molopo	Biloela	American	Molopo
Total CP yield									
N-rates (kg/ha)									
0	0.45	0.35	0.35	0.84	1.03	0.84	0.28	0.34	0.36
40	0.78	0.38	0.42	1.05	1.02	1.07	0.48	0.39	0.45
80	0.75	0.46	0.43	1.20	1.37	1.28	0.66	0.56	0.52
P_2O_5 rates (kg/ha)									
0	0.59	0.29	0.39	0.77	1.14	1.36	0.50	0.45	0.42
38	0.60	0.45	0.37	1.01	1.02	1.33	0.50	0.39	0.47
76	0.79	0.44	0.45	0.92	0.99	1.17	0.43	0.46	0.43
Cultivar									
Mean	0.66	0.40	0.40	1.03	1.14	1.06	0.48	0.43	0.44
Standard error		±0.054[a]			±0.42[b]			±0.46[b]	
N-rates (kg/ha)	0	40	80	0	40	80	0	40	80
Mean	0.38	0.53	0.55	0.90	1.05	1.29	0.33	0.44	0.58
Standard error		±0.24[a]			±0.060[a]			±0.017[a]	
P_2O_5 rates (kg/ha)	0	38	76	0	38	76	0	38	76
Mean	0.42	0.47	0.56	1.09	1.12	1.29	0.46	0.45	0.44
Standard error		±0.031[a]			±0.059[b]			±0.042[b]	

[a] Significant at P = 0.05 level.
[b] Not significant.

Table 5. Forage dry matter (DM) yield (Mt/ha) and total crude protein (CP) (kg/ha) at Chitala (MT/ha) for the years 1977/78, 1978/79, and 1979/80.

	1977/78 cultivars			1978/79 cultivars			1979/80 cultivars		
Treatments	Biloela	American	Molopo	Biloela	American	Molopo	Biloela	American	Molopo
Forage DM yield									
N-rates (kg/ha)									
0	0.82	0.88	0.90	5.30	5.88	4.93	5.21	4.46	4.56
40	1.33	1.77	1.09	6.73	9.12	6.18	6.70	5.89	7.10
80	2.06	2.19	2.03	8.49	10.43	9.27	10.09	7.90	8.38
P_2O_5 rates (kg/ha)									
0	1.55	1.38	1.56	7.71	7.57	7.41	6.94	5.61	7.52
38	1.28	1.76	1.32	5.85	8.59	6.10	7.59	6.15	5.85
76	1.40	1.65	1.13	6.97	9.27	6.87	7.48	6.50	6.67
Cultivar									
Mean	1.41	1.59	1.34	6.84	8.48	6.79	7.33	6.09	6.68
Standard error		±0.17[b]			±0.34[a]			±0.36[b]	
N-rates (kg/ha)	0	40	80	0	40	80	0	40	80
Mean	0.87	1.38	2.09	5.37	7.34	9.40	4.75	6.56	8.79
Standard error		±0.15[a]			±0.52[a]			±0.23[a]	
P_2O_5 rates (kg/ha)	0	38	76	0	38	76	0	38	76
Mean	1.49	1.45	1.39	7.56	6.84	7.70	6.69	6.53	6.88
Standard error		±0.20[b]			±0.49[b]			±0.32[b]	

(continued)

Table 5. Concluded.

Treatments	1977/78 cultivars			1978/79 cultivars			1979/80 cultivars		
	Biloela	American	Molopo	Biloela	American	Molopo	Biloela	American	Molopo
Total CP yield									
N-rates (kg/ha)									
0	60	121	65	392	448	392	208	162	177
40	95	139	75	490	780	514	332	300	346
80	139	166	139	504	775	615	676	456	480
P_2O_5 rates (kg/ha)									
0	113	161	115	590	592	554	400	283	381
38	88	142	87	323	686	506	348	310	302
76	94	123	78	474	725	461	467	325	322
Cultivar									
Mean	98	142	93	462	668	507	405	306	335
Standard error		±4[a]			±61[b]			±25[b]	
N-rates (kg/ha)	0	40	80	0	40	80	0	40	80
Mean	82	103	148	411	595	631	182	326	538
Standard error		±11[a]			±33[a]			±19[a]	
P_2O_5 rates (kg/ha)	0	38	76	0	38	76	0	38	76
Mean	130	106	76	579	505	553	355	320	371
Standard error		±21[b]			±40[b]			±30[b]	

[a] Significant at P = 0.05 level.
[b] Not significant.

Table 6. Forage dry matter (DM) yield (Mt/ha) at Chitedze and Chitala.

Treatments	Chitedze 1979/80	Chitala 1978/79	Chitala 1979/80
Buffel grass alone	5.22	3.80	2.53
Buffel grass in Siratro	2.59	4.92	2.69
Siratro in buffel grass	0.99	1.74	0.88
Buffel grass in Neonotonia	2.27	5.13	3.13
Neonotonia in buffel grass	0.96	0.37	0.08
Buffel grass in cook stylo	1.92	4.01	3.39
Cook stylo in buffel grass	0.52	1.92	0.06
Buffel grass in Centrosema (Hamata stylo)[b]	2.30	4.26	2.74
Centrosema (Hamata stylo)[b] in buffel grass	0.45	2.65	0.91
Siratro alone	1.94	4.13	1.32
Neonotonia alone	1.10	4.30	0.43
Cook stylo alone	0.90	5.59	0.77
Centrosema (Hamata stylo)[b] alone	0.65	6.33	2.85
Mean	1.68	3.83	1.67
Standard error	±0.21[a]	±0.65[a]	±0.40[a]

[a] Significant at P = 0.05 level.

[b] Hamata stylo was substituted for Centrosema at Chitala.

similar Molopo. There was a tendency for all cultivars to respond favourably to increasing nitrogen application rates. The forage productivity response to nitrogen application was significant in all years but the response to phosphate application was generally insignificant.

Crude protein yields were comparable among the three cultivars in all years except in the 1977/78 season when Biloela produced the largest amount of total CP. At Chitala, on the other hand, there was a tendency for the American variety to outyield the other cultivars. This was particularly evident in the first 2 years (Table 5). In the 3rd year there was a shift toward Biloela. This was attibuted to a 10% increase in the amount of rainfall at this site that year. All cultivars responded significantly to nitrogen fertilization rates, but there was no significant response to phosphorus application. At both Chitedze and Chitala, the soils have adequate amounts of available phosphates; this explains the lack of response (Matabwa, personal communication). It appears from this study that cv. Biloela does well in the subhumid environments whereas cv. American could be adapted to the drier near semi-arid areas. This fact was established in a separate study (Dzowela and Msiska 1984).

Growing buffel grass in association with tropical forage legumes benefits the grass component in the system. This fact was evident at Chitala where the forage production of the buffel grass increased as a result of a legume component. This increase could be either due to utilization of the nitrogen fixed by the legume or the smothering of weed species by the legume. At Chitedze, on the other hand, this advantage of the legume component was not very obvious (Table 6). The best association appeared to be that involving buffel grass/Hamata stylo followed by buffel grass/Siratro and then buffel grass/Cook stylo at Chitala. For Chitedze, the best association was one involving buffel grass/Siratro followed by buffel grass/Neonotonia, buffel grass/Centrosema, and then buffel grass/Cook stylo.

ANIMAL PRODUCTIVITY OF IMPROVED PASTURES

Fertilized Grass Pastures vs. Legume-Based Pastures

A number of tropical forage grasses and legumes have been agronomically evaluated in Malawi. Of the *Panicum* species, the local strain, Ntchisi panic grass has shown greatest potential (Anonymous 1975). Its productivity potential in a cutting situation has been found to be three-fourths of that achievable by *P. purpureum* x *P. typhoides* (Dzowela 1978). Before this the Ntchisi panic grass was regarded as a grass suitable for "cut and carry" purposes. However, observations at Chitedze Agricultural Research Station have established that Ntchisi panic grass can persist for more than a decade in a grazing situation.

Of the newly introduced Rhodes grass cultivars from Kenya, the Masaba strain has shown good forage and regrowth characteristics (Dzowela 1984). It responds very well to inorganic nitrogen fertilizer, but with the current increased costs of this form of fertilizer, the option is to incorporate a tropical legume component in the pasture system. The legume component has the dual purpose of raising the nutrient status of the pasture system with respect to CP and calcium and phosphorus and of contributing biologically fixed nitrogen to the system to the benefit of the grass component as well (Thomas 1973). Earlier work conducted in Malawi has established the compatibility of Rhodes grass with *Desmodium uncinatum* cv. Silverleaf (Thomas 1976).

Attempts to seek more permanent pasture species for Malawi (Anonymous 1975) identified the *C. nlemfuensis* cultivar, Henderson No. 2 star grass, as a productive tropical grass. It produced good amounts of digestible forage and was able to support grazing animals through the wet season better than Rhodes grass.

A study comparing the performance of animals grazed on Ntchisi panic grass, Masaba Rhodes grass, and Henderson No. 2 star grass, a grazing trial was conducted at Chitedze Agricultural Research Station. The three pastures grown in pure stands receiving 40 kg of inorganic nitrogen application per hectare annually were compared with a Masaba Rhodes/Silverleaf desmodium mixed sward without the inorganic nitrogen application. Paddocks measuring 1.5 ha each were arranged in a randomized complete block design with three replicates. Each paddock was subdivided into four quarters to facilitate sequential rotational grazing by 2-year old Malawi Zebu heifers using the "put and take" grazing-management system (Mott 1960; Mott, personal communication). There were eight test animals permanently assigned to each pasture along with variable numbers of additional "graze" animals to use excess forage. Forages were sampled for dry matter (DM) before grazing. The animals were weighed on a 28-day interval throughout the wet season, which lasted for 5 months in 1982/83 and 1983/84.

The forage and animal productivity potential of Ntchisi panic grass is evident (Table 7). It produced significantly better average daily gains (ADG), total gains, and total forage than the other pastures, although ADG was not different from that achieved from Rhodes grass/Silverleaf pasture. Star grass supported the highest number of animals despite its relatively poor animal productivity. Intake and digestibility-related problems were suspected in the absence of chemical analytical data. In terms of forage productivity, the Rhodes grass pastures in pure and associated swards with Silverleaf desmodium were comparable; the better animal performance of the mixed pasture was attributed to higher nutrient intake afforded by the legume component in the mixture. In terms of ADG, the pure Rhodes grass pasture had similar production values to the Rhodes grass with Silverleaf in 1983/84 for some unknown reasons, while chemical analyses were being awaited.

Star grass, closely followed by Ntchisi panic grass, provided the most grazing days, although its forage production was lower than that of Ntchisi and comparable to that of the Pure Rhodes grass and Rhodes grass and Silverleaf desmodium. The fact that individual animal ADGs were lowest on star grass relative to the other pastures does confirm some intake and digestibility-related problems with this grass.

Legume Reinforced Natural Grassland

Preliminary investigations by the UNDP/FAO Project/75/020 indicated the value of introducing

Table 7. Average daily gains (ADG), total grazing days, total liveweight gains and dry matter (DM) forage offered

Pasture	ADG (kg/ha)	Grazing days (days/ha)[b]	Total gain (kg/ha)	Total seasonal forage DM (Mt/ha)
1983/83				
Star grass	0.42^{a}	1628^{a}	720^{a}	11.45^{a}
Ntchisi panic grass	0.67^{b}	1451^{ab}	916^{b}	18.40^{b}
Rhodes grass (pure)	0.49^{a}	1340^{b}	662^{a}	11.33^{a}
Rhodes grass + Silverleaf	0.62^{b}	1184	669^{a}	11.17^{a}
1983/84				
Star grass	0.61^{a}	1960^{a}	911^{a}	14.18^{a}
Ntchisi panic grass	0.67^{b}	1837^{a}	950^{a}	15.56^{a}
Rhodes grass (pure)	0.70^{b}	1177^{b}	527^{b}	14.61^{a}
Rhodes grass + Silverleaf	0.70^{b}	1165^{b}	526^{b}	14.71^{a}

[a] Figures within a column with the same letter do not differ significantly, following Duncan's New Multiple Range Test.

[b] Product of length of grazing season in days and number of grazing animals (testers and grazers).

Table 8. Comparative liveweight gains of stylo-based and improved natural grasslands.

Treatments	Total gains in kg/animal from 26/6/79 to 18/8/79[a]	Mean daily gain in kg/animal
Stylosanthes-based grasslands	25.79	0.486
Unimproved	-3.56	-0.067

[a] Based on a group of 13, 2-year old steers.

Stylosanthes guianensis cv. Cook stylo as a means of improving the forage quantity and quality of extensive natural grazing areas, particularly in the dry season under the Western Mzimba ecological conditions in Northern Malawi. Liveweight gains of approximately 0.25 kg/day/animal were obtained between May and November when cattle generally lose weight (Van Empel, personal communication). An attempt, therefore, was made to determine the optimum stocking and productivity potential of these Stylosanthes-based grasslands (Table 8).

The potential of improving the natural grasslands by legumes cannot be overemphasized. The Cook stylo was capable of arresting liveweight losses at the time the group on unimproved grassland were losing weight. This was attributed to better intakes and digestibility of the legume-reinforced forage.

PRIORITIES FOR FUTURE RESEARCH AREAS

Although reliable research information has been generated, this type of research has primarily served the interest of the commercialized farmers who own only 4% of the national cattle herd of 0.87×10^6. The mixed smallholder farmer will be the main target of research efforts for the 80s. The need to develop a research technology that will be able to raise the standard of living of the smallholder through increased livestock productivity will be highlighted within the adaptive or farming systems research concept. An integration of improved pastures in the farming system of motivated dairy and beef farmers will take the first priority. Undersowing of improved pasture species in maize crops with the view to utilize crop residues better during the dry season will be the focal point of this work.

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PASTURE RESEARCH AND DEVELOPMENT IN ETHIOPIA

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Abstract *Ethiopia is an agricultural country with a diverse climate varying from cool tropical highlands to arid lowlands. It has the highest number of livestock in Africa. The majority of the human as well as the livestock population are found in the highlands where there is reliable rainfall. The major source of feed for livestock in Ethiopia is natural pasture, which is low in quantity and quality. Hence, both undernutrition and malnutrition are major problems for the greater part of the country and consequently livestock productivity is low.*

To improve the feed shortage problem, over the past 15 years a number of grass and legume species have been tested in various ecological zones. More than 20 species of both grasses and legumes have been selected for the highland, mid-altitude, and lowland zones. The selected species are higher in yield and nutritional value than the naturally occurring swards. At present, oats, vetch, fodder beet, Rhodes grass, and alfalfa are being used by state farms and peasants in dairy cooperatives. There is no large-scale pasture seed production and the unavailability of seeds has seriously affected forage development in Ethiopia.

Ethiopia has a total land area of 122 x 10^6 ha and is located bwtween 3° and 18° northern latitude. It is generally a mountainous country with a high Central Plateau (1,800-3,000 m) and extensive lowland areas to the south, southeast, and northeast. The climate is very diverse, largely determined by the country's mountainous terrain and primarily by its high altitude. The Ethiopian highlands have an almost temperate climate with maximum temperature rarely rising above 25 °C and an annual rainfall greater than 1,000 mm. In contrast, the lowlands experience high temperatures, with erratic rainfall of usually less than 700 mm annually. As a consequence of the climate, most of the cultivated land and the peasant population are found in the rainfall areas around the highlands.

Ethiopia's economy is dominated by the agricultural sector and it accounts for about 50% of the gross domestic product (GDP). Livestock and livestock products contribute about 35% of the agricultural output. The livestock population is estimated to be 27 x 10^6 cattle, 42 x 10^6 sheep and goats, 7 x 10^6 equines, and 1 x 10^6 camels. The most important products of the ruminant livestock population are traction, milk, and meat. Cattle play an important role in crop production in that about 6 x 10^6 ha of cultivated land depends on draft power for ploughing.

Livestock are vital to the country's economy and could contribute more if the potential is exploited. One of the major reasons for low livestock productivity is feed inadequacy. Ruminant feed resources are almost entirely based on natural pasture and crop residues. Grazing conditions are unfavourable for more than half of the year due to the marked seasonality of rainfall distribution and also to the high stocking rates in many areas. Overgrazing, particularly in the highlands and around permanent water points, is a serious problem. In the lowlands, although there seems to be an abundance of grazing area, the situation is constrained by prolonged dry areas and scarce watering facilities.

NATURAL PASTURE IN ETHIOPIA

In general, arable agriculture is the main use of land where the average annual rainfall exceeds 600-700 mm. The better soils are used for cropping, and the slope of hills and seasonally waterlogged areas are allocated to permanent grazing. In areas receiving less than 600-700 mm of average annual rainfall, extensive pastoralism is practiced; most of the land is under natural grassland that may be associated with woodland in the wetter areas. Considering the country as a whole, grazing areas account for 53% of the total area.

Although the acreage of grazing areas (65 x 10^6 ha) seems to be large, the yield and quality of the pasture is low. In the highlands, annual pasture yields range from 1 to 2 t dry matter (DM)/ha on freely drained, relatively infertile soils, up to 4-6 t/ha from seasonally waterlogged fertile areas. A grazing trial conducted at Holetta Research Station (highland zone) indicated that natural pasture under good management can support approximately 2.5-3 livestock units (LSU)/ha from July to December (IAR 1981). The communally owned pasture lands in similar areas support far less animals. The carrying capacity of natural pasture in the mid-altitude and lowland areas is about 1 LSU/1-5 ha (FAO 1974). Rainfall is the major factor influencing forage productivity.

With the diverse climate in Ethiopia, there are a number of valuable grass and legume species occurring naturally in various areas. The highlands are rich in the variety pasture species and especially in legumes whose proportion tends to increase with increasing altitude. A wide range of annual and perennial *Trifolium* species and annual *Medicago* species are common. At lower altitudes the native legumes are less abundant and grasses predominate. At present, the International Livestock Centre for Africa (ILCA) has a strong forage legume program that involves the collection and evaluation of native legumes.

CULTIVATED PASTURE AND FODDER CROPS

Tested Pasture Species

Over the past 15 years, several annual and perennial forage species have been introduced and tested at different ecological zones ranging in altitude from 600 to 3,000 m above sea level. Research results and development testing have identified many species of herbage suitable for the various ecological conditions in the country. The list of recommended species is given in Table 1.

In general, the introduced species are higher yielding than the naturally occurring swards and have higher nutritional value. In addition, the length of the green feed period/growing season is longer for

Table 1. Recommended pasture and fodder species for various environments.

Major zone	Species
Highlands (above 1,800 m)	Dactylis glomerata, Phalaris tuberosa, Phalaris arundinacea, Festuca arundinacea, Lolium perenne, Setaria sphacelata, Avena sativa, Beta vulgaris, Vicia dasycarpa, Vicia atropurpurea
Mid-altitudes (1,000-1,800 m)	Chloris gayana, Panicum coloratum, Panicum maximum, Melinis minutiflora, Pennisetum purpureum, Cenchrus ciliaris, Zea mays, Sorghum sudanese, Sorghum vulgare, Sorghum almum, Lablab purpureus, Medicago sativa, Desmodium uncinatum, Leucaena leucocephala
Lowlands (below 1,300 m) usually under irrigation	Cenchrus ciliaris, Chloris gayana, Panicum maximum, Panicum coloratum, Pennisetum purpureum, Medicago sativa, Leucaena leucocephala

cultivated pastures than for the native pastures. Although the list of species that could be successfully grown in Ethiopia appears long, very few of them are in practical use. Out of the species already mentioned that have been tested and selected, fodder oats (Avena sativa), vetches (Vicia dasycarpa), and fodder beet (Beta vulgaris) are gaining acceptance and popularity in the highlands. In the mid-altitude and lowland areas, two widely cultivated species are Rhodes grass (Chloris gayana) and alfalfa (Medicago sativa).

In suitable areas, yields of oats/vetch mixture are commonly of more than 8 t DM/ha and that of fodder beet is from 15 to 20 t DM/ha. These crops are commonly grown by state-owned dairy farms and by farmers in dairy cooperatives. In the Arsi region, because of a strong outreach program of the Arsi Rural Development Project (ARDP), there has been a widespread acceptance of oats and fodder beet among farmers. In some other parts of the highlands, farmers grow local varieties of oats both for food and for feed purposes. Rhodes grass and alfalfa are extensively used in state farms, research stations, and settlement areas.

Pasture Establishment

For successful pasture and fodder crops establishment, thorough land preparation is essential. In Ethiopia, large-scale pasture development requires at least two field operations, ploughing and harrowing. Depending on the soil type, more than two operations may be required in some areas. This is often true in many highland regions. The use of chemical fertilizers during establishment is very limited because of the high prices. Significant quantities of artificial fertilizers, mainly diammonium phosphate, are only currently used on forage crops within state farms.

Establishment of pastures is relatively difficult in the highlands as compared to the humid warmer and lower areas. This is mainly because of unfavourable soil and climatic conditions and severe competition from weeds during the wet season. Conditions of waterlogging, relatively low soil temperatures, and low radiation limit the establishment and subsequent growth of pastures in the highlands (Haile 1983). To take advantage of favourable environmental conditions, during the light rains in March and April, it is recommended to plant pasture seeds during this season. In some years, the length of the light rains is too short and, thus, planting is done early during the onset of the heavy rains (usually June). Annual fodder species such as oats and vetch are usually planted in June, except maize and Sorghum, which are planted in April and May. In newly established stands, weeds are usually controlled by mowing or topping. This method gives a reasonable degree of control, especially against broadleaf weeds.

Establishment of grasses and legumes under irrigation requires more careful land preparation. The land has to have a very even slope and must be irrigated before planting to germinate the weeds. After the weeds emerge, they are killed by rotivation, and the field can then be planted.

Management and Utilization

Natural pastures are poorly managed throughout the country. Overstocking and overgrazing has resulted in serious land degradation, the disappearance of valuable species, and the spread of unpalatable species. Most overgrazed grasslands, particularly in the highlands, are dominated by Pennisetum schimperi, a course unpalatable grass that is grazed only when there is no alternative. In some areas, it dominates as much as 80% of the ground cover, thereby reducing the effective production to a small fraction of the potential (Blair 1970).

Under the present communal system of grazing, it is difficult to control the number of livestock and, not surprisingly, overgrazing and overstocking are common features (Haile 1983). The current information of Peasant Associations and Producer Cooperatives has now created new possibilities for introducing innovations such as the control of numbers of grazing stock. Many peasant associations have started allocating areas to be reserved for hay and grazing. In settlement project areas that are run by the Relief and Rehabilitation Commission (RRC), there is a land use plan, and therefore, croplands, pasture, and forestry areas are delineated.

Improved pastures are not usually grazed during first year. However, in the humid warmer areas the growth of the tropical pasture species such as Rhodes grass is very fast and, therefore, they can be cut for hay or silage in the year of establishment. In the highlands, pasture species grow slowly and need the first year for establishment.

Established pasture stands are either harvested for conserving in the form of hay or silage or grazed in situ. Species such as Rhodes grass, Panicums, and alfalfa are highly productive. Under rainfed conditions, two harvests are quite common and the first harvest after mid July is used for making silage. During this time, weather conditions make it impossible to make hay. The regrowth is then harvested for hay making, sometimes in October. The total yield for two harvests is 10-12 t DM/ha. Following hay making, the pasture fields provide considerable grazing for about 2 months (November and December). In the irrigated lowlands, alfalfa and Rhodes grass are very important. About eight harvests from Rhodes grass and 8-10 harvests from alfalfa are common per year. Their yield range is 45-55 t DM/ha/year. This yield is about four times higher as compared to the yield under rainfed conditions. In these areas, the cut and carry technique is used in combination with grazing and hay making.

In the highlands, oats and vetch are very useful for green feeding, hay, and silage. Some small-scale farmers have realized the feed value of oats and vetch and have started these in their own fields. Annual yield of oats/vetch mixtures is 6-10 t DM/ha. Another high-yielding and popular annual crop for the high-altitude areas is fodder beet. Beet is usually planted directly during the light rains or seedlings are raised in a nursery and transplanted during the main rains. In suitable and fertile areas, tuber yields of some 15-20 t DM/ha can be achieved. The storage of beets does not present a problem because the tubers can be left in the field and dug out from the soil when needed. Fodder beet is particularly suitable for individual farmers because it can be grown as a backyard crop.

Maize and sorghum are grown on some state dairy farms and research stations for silage and green feeding. In the mid-altitude subhumid zones, maize and sorghum stovers provide a considerable quantity of low-quality roughage. Cereal straws of barley, wheat, teff, and pulse crop residues (horse beans, field peas, etc.) are also important components of the dry-season livestock diet in the highlands.

Seed Production

Any substantial forage development program is entirely dependent on a reliable domestic seed supply. In Ethiopia, although potential areas for pasture and fodder crops development and seed production are extremely diverse in terms of altitude, climate, soil types, and farming systems, there is a tremendous lag in pasture seed production. One obvious reason for this lag is the scarcity and/or unavailability of seeds of required species. At present, Ethiopia is not producing seeds of the appropriate species in sufficient quantity to have any significant effect at the farm level. The techniques for large-scale pasture seed production have not yet been adopted in the country.

The Ethiopian seed enterprise (ESE) has a national mandate to produce the required agricultural seed; however, the current priority of the enterprise is the provision of cereal grain seeds, food legumes, and oilseeds. It has minimal involvement with fodder seed production, i.e., oats and vetch, and none with pasture seeds. The Institute of Agricultural Research (IAR) and the ARDP have been involved with the production of seeds of various species; however, it is primarily to meet the requirements of their programs, and they distribute only small quantities to a few other government organizations. In general, pasture and fodder seed production is in its infancy. For large-scale development in state farms and settlement areas pasture seeds are usually imported from Kenya and Australia.

Other Aspects

The Soil and Water Conservation Department (SWCD) of the Ministry of Agriculture established in 1981 has begun work in 2% of the 35 x 10^6 ha of badly eroded areas that require urgent attention. Revegetation is one of the techniques that is being adopted and advocated in combating soil erosion and to this effect a range of grasses, creeping legumes, and leguminous fodder trees are being encouraged. It is expected that because the species are edible that livestock keepers will take interest in them. In 1983/84, it was projected that the department would construct 200,000 km of bunds, of which almost 40,000 km would be planted with grasses and legumes (Ministry of Agriculture, Ethiopia 1984). It is anticipated that this will have an important contribution to the livestock industry because the forages will be used on a cut and carry basis. Recently, the department has initiated a seed-production program to meet its own requirements for revegetation that involved a contract arrangement with peasants to multiply seeds of some species collected from ranches and livestock exclusion areas.

Application of Scientific Information by Livestock Owners

Today there is an active expansion in the number of dairy producers' cooperatives in the highlands and midaltitude areas. These newly emerging cooperatives have communally owned herds of crossbred cattle that require better feeding. Accordingly, there is a growing interest in the use of improved species of pastures and fodder crops. Crops such as oats, vetch, fodder beet, and in some cases alfalfa and Rhodes grass are grown for hay and green fodder. There is an increasing, and as yet unsatisfied, demand for seeds of these species. In contrast, individual farmers are slow to accept improved species or practices, because their main priority is for food crop production and they are reluctant to devote extra land and scarce labour to forage production. The situation is further constrained by the unavailability of seeds.

In the Arsi region, where there has been a strong extension program, marked responses have been found. In this region, the package includes the sale of crossbred cattle to farmers, and also demands that purchasing farmers have at least 1 ha of fenced grazing land and planted fodder crop (beet, oats, or vetch).

RESEARCH METHODOLOGIES

Acquisition of Germ Plasm and Selection

During the past decade, several tropical and temperate pasture and fodder species have been introduced from South America, North America, Europe, Australia, and some parts of Africa. Most of these genetic materials were obtained through the Food and Agriculture Organization (FAO) of the United Nations. Some attempt is being made by the IAR to collect promising indigeneous species from around research stations and substations. Presently, ILCA is introducing a wide range of species and also has an active program of collecting and evaluating indigenous species, mainly legumes.

Establishment

Further agronomic studies, such as seeding rate, seeding time, etc., should be conducted on promising species/varieties. The conventional method of establishing pasture is tedious and labour demanding, especially in the highlands. Low-cost establishment methods such as undersowing or oversowing could be more attractive to farmers. Undersowing studies have been conducted both in the highlands and in the medium altitude zone using the best food and forage crops for the regions. In the highlands (Holetta Research Station), wheat and barley were undersown with alfalfa, annual clovers, tall fescue, perennial rye grass, Setaria, and Phalaris tuberosa. The planting of both the cereals and forage species was done at the same time. All undersown forage crops successfully established except alfalfa, and there was no significant grain yield reduction of the cereals. Overall establishment of the forage species was much better under wheat than under barley (IAR 1982, 1983). Because fallowing of croplands is a common practice in the highlands, undersowing cereals with forage crops could significantly improve the feed shortage problem of the region.

In the mid-altitude area, at two locations maize was undersown to Desmodium, phaseay bean, Rhodes grass, Panicums, and Cenchrus after the first weeding of maize. Almost all species established, and there was no maize yield reduction. Rhodes grass and Desmodium in particular showed superior establishment and persistence in the following years. A similar study conducted in a low rainfall area (less than 700 mm annual rainfall) was unsuccessful.

Another important method of establishing some perennial grasses is by using vegetative parts. Establishment of temperate species in the highlands particularly in waterlogged sites is extremely difficult. A trial was conducted to compare the establishment of various species in waterlogged areas using seeds and root splits. Two cultivars of P. tuberosa namely Australia and Sirocco, Lolium perenne, Festuca arundinacea, Phalaris arundinacea, Setaria sphacelata, and Trifolium tembense were included. P. tuberosa Sirocco, L. perenne, and T. tembense successfully established from seeds but failed to persist in the following years. For the other species, root split propagation was more successful and required less intensive land preparation and management such as weeding. Festuca, P. arundinacea and Setaria are highly adapted to waterlogged conditions and can be established very easily by using root splits.

To improve the vegetation composition and nutritional value of degraded natural pastures, oversowing legumes and grasses has been tried both in the highlands and in the midaltitude areas. Results indicate that vetches (Vicia dasycarpa and V. atropurpurea) and local clovers are successful in the highlands, whereas Rhodes grass and Siratro are potential species for oversowing. In all cases, the oversowing had to be done early before the start of the rainy season, and a slight sod disturbance was advantageous over undisturbed sod (IAR 1982).

Management

Improved pastures deteriorate very rapidly and are easily invaded by weeds unless proper management decisions are made. To keep the pastures in good condition, encroaching annual weeds should be removed regularly. Application of nitrogenous fertilizers on pure grass pastures keeps them productive for longer periods. Unless the pasture is cut clean once a year and about 50 kg N/ha is applied, productivity will decline from year to year. There is very limited information on grazing response and carrying capacity of introduced species, particularly for the temperate ones. Rhodes grass, which thrives exceptionally well under rainfed conditions, can support up to 6 LSU/ha during the wet season.

Seed Production

Information on pasture seed production is limited in Ethiopia. Despite increasing demands for pasture and fodder seeds, this area has received little attention so far. It has been observed that many of the species that grow in Ethiopia seem to have no problem in flowering and seed setting. Data on seed yields under Ethiopian conditions are given in Table 2. Small quantities are often collected from experimental plots and unharvested portions of bulk fields. Preliminary work on vetch

Table 2. Seed yields of pasture and fodder crops.

Species	Seed yield (kg/ha)
Oats	1500 - 3000
Vetch	500 - 1000
Fodder beet	400 - 600
Leucaena	1500 - 2600
Alfalfa	300 - 400
Desmodium	200 - 400
Rhodes grass	200 - 250
Trifolium sp.	200 - 300
Cocksfoot	100 - 150
Sudan/Colombus	600 - 800
Panicum sp.	150 - 200

indicated that seed yields can be increased by supporting the plant on frames or fences, which allows multiple harvesting.

Utilization

Grazing is by far the commonest method of feeding livestock in Ethiopia. However, the potential of the grazing areas and of improved species in the highlands and rangelands is not known; therefore, there is no systematic method of utilizing grazing areas. The general practice is to graze them year round, and, in some cases, leave some portion as a standing hay. The standing hay has very little nutritional value. In the central highlands, results of grazing trials indicate that a good way of using the pastures is to stock half of the area at a higher rate (3-4 LSU/ha) during the wet season and reserve the rest for hay, which is normally cut in late October. The hay is used as a dry-period supplement in December when the animals start losing weight. Regardless of the stocking rate, grazing animals are bound to lose weight in the dry period because of the poor quality of the standing hay.

Most of the introduced and recommended species are suitable for hay, silage, and grazing. Because of a lack of technical know-how and machinery, the making of silage is mainly restricted to research stations and state farms. Common silage crops are maize, sorghum, oats/vetch, and in some cases Rhodes grass and even natural pastures. Fodder crops such as alfalfa, oats/vetch, and leucaena are quite often used for green feeding. Information on the assessment of improved forages in terms of animal productivity (meat, milk, etc.) is limited and there is a need to undertake studies in this area.

FUTURE RESEARCH PRIORITY AREAS

Considering the available information on pasture research and development in Ethiopia, the following areas need further investigation:

It has been stressed that one of the major constraints for forage development is the shortage of seeds of desired species. Ideal sites, therefore, for seed production have to be identified and the agronomic techniques need to be thoroughly investigated. Identification of suitable seed-production areas will not be a difficult task because there are some 117 adaptation trial sites under the Ministry of Agriculture in addition to those under IAR and ILCA.

. Development of low-cost establishment techniques encourages farmers to grow improved forages. Studies such as undersowing, oversowing, etc., need to be strengthened, refined, and developed for the various ecological zones and farming practices.

. Information regarding the economics of improved forages is seriously lacking. Recommended forage species need to be assessed in terms of milk, meat, etc., and an economically viable system of feeding has to be developed. This type of research can best be done on state farms where most of the required resources are already available.

. Ethiopia has a diverse climate and, consequently, it has a wide range of naturally occurring forage species. Collection and evaluation of indigenous species may prove to be useful for future forage development schemes and pasture improvement programs because they are well adapted to the local soil environment. At present, ILCA has a program of collecting and evaluating native species, but there has to be a national effort to cover the various ecological zones. Because

IAR has research stations in some of the most important ecological zones, collection should not be difficult.

. It has been pointed out that natural pastures are major feed sources in the country. Because the pastures are deteriorating both in quantity and in quality, pasture management and improvement programs should be initiated in livestock-production areas. There are already some programs within IAR and ILCA, but more programs of this kind are needed.

. Forage legumes provide high-quality feed for livestock and also contribute significant amounts of biologically fixed nitrogen to the soil. In Ethiopia, there are a number of well-adapted legumes that have been introduced and also naturally occurring ones. However, so far, no tangible studies have been conducted to assess the potential of the most promising legumes and they are not as yet integrated in crop production. Research along this line and the establishment of a soil microbiological laboratory to determine and produce rhizobial strains could be very beneficial.

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PASTURE RESEARCH IN BURUNDI

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Abstract *Pasture research in Burundi has concentrated on introducing and screening a few species in the different ecological zones.* Seteria sphacelata *is adaptable in the central plateau, whereas* S. splendida *does well in both the central plateau as in the higher altitude areas.* Tripsacum laxum *and* Pennisetum purpureum *adapt to a wide range of ecological conditions including the high altitude, central plateau, and long land areas. Appropriate management technologies have been developed for these species.*

In Burundi, like other countries of Eastern and Southern Africa, livestock have traditionally been kept on the basis of natural pastures. With the ever increasing human population, the area available for agriculture and livestock development per capita is not only continually decreasing but has gradually deteriorated. The problem of feeding livestock has, therefore, become acute particularly during the dry season.

Range- and pasture-improvement techniques (division of grazing land into paddocks, rotational grazing, suppression of bush fires, hay making and optimal stocking rates) bring about qualitative and quantitative improvement of the pastures and allow local herds to survive the dry season. However, these techniques are inadequate if we want to increase production significantly. For this reason the Burundi government decided to acquire forage germ plasm adaptable to the different altitudes in the country (from 775 m at Lake Tanganyika to 2,200 m in the high plateau). Pasture seeds and clones from regions that experience similar climatic conditions were imported to Burundi.

These strains were also chosen according to their yield potential and those that do not require mechanization.

PRESENT STATE OF PASTURES RESEARCH

Among the grasses evaluated only four have proven adaptable and of good nutritive quality: *Tripsacum laxum*, *Pennisetum purpureum*, *Setaria splendida*, and *Setaria sphacelata*. Observations were made on establishment and production in the different ecological zones following the altitudes. The four Gramineae studied fall into two user groups: fodder plants (*T. laxum* and *P. purpureum*), and those for grazing (*S. splendida* and *S. sphacelata*). Both intensive and extensive cultural practices have been used in managing these species and it is apparent that these forrage plants can tolerate a range of management levels.

P. purpureum grows rapidly and tends to be stemmy and, therefore, has to be harvested frequently to ensure the production of forage of high digestibility coefficients and crude protein (CP) contents. Harvested material can be ensiled or stall fed. Stands of elephant grass do not persist for more than 2 years in the lowland areas if not irrigated. In the highland areas, elephant grass persists for many years and is planted on contours to control soil erosion on slopes.

Seteria species are adaptable in the central plateau and highland areas. *S. sphacelata* does best in the central plateau, whereas *S. splendida* does better in the highland areas. Setarias are either grazed in situ or stall fed. Like elephant grass, Seterias can be planted in contours to control soil erosion. Further, it was observed that *T. laxum* and *P. purpureum* have very high revival rates and a tendency to produce a high number of tillers. Setaria flowers and produces seeds while flowering in *P. purpureum* is common, but this seed is poor.

Pasture Preparation

Soil preparation for all four gramineae is identical with mechanization, such as mechanical tilling (tractor or animal traction) at a depth of 30 cm, a rotavator (facultative), or harrow in crisscrosses. Soil preparation without mechanization would include cleaning the fields and deep tilling (30 cm) with a hoe and covering under the soil the organic materials from the top of the soil.

Farmyard Manure

In the intensive system with poor soil fertility, manure application at a rate of 40 t/ha must be provided before planting T. laxum, P. purpureum, and S. sphacelata, and this quantity can be split up. In the case of T. laxum and P. purpureum the initial application will be 20 t/ha, with the remaining 20 t being applied after establishment. Seteria can be planted on residual manure applied on a companion crop of maize. The recommended manure applications are 30 t/ha for maize, followed by 10 t/ha at the time of planting Setaria under the maize crop. Manure application has been found to improve grass establishment and productivity. Stoloneferous T. laxum and P. purpureum is planted at a depth of 15-20 cm and at a spacing of 50 x 50 cm, i.e., 40,000 plants/ha at a depth of 15-20 cm. It is recommended that the rhizomes should have at least three nodes, of which two are covered by the soil, and planting should be done when the soil moisture is high. Splits of seteria are more commonly used as propagation material than seeds.

Experience in Burundi has shown that elephant grass and Guatemala grass have to be planted before 15 January and in the case of Seteria the planting should be at the beginning of March, and planting should be completed by the beginning of April. These dates must be adhered to so that the plants receive adequate precipitation to develop their vegetative and root systems before the dry season.

Cultivation

T. laxum and P. purpureum require weeding 1 month after planting and again at the end of the rainy season/beginning of the dry season (June). During the following years, three weedings will be necessary: the first at the beginning of the rains (October-November), the second in the middle of the season (March), and the third at the end of the rainy season (June). To avoid weeding, mulch (15-20 cm thick) can be put in between the rows. This delays the appearance of weeds but cannot be recommended because it is difficult to obtain sufficient material for mulching.

Productivity

Yield rates (green matter per ha at 2 cuttings per year) were obtained in several zones: (a) T. laxum production was 50-60 t green materials/ha in the low altitude areas, 40 t/ha in the high altitude, and 35 t/ha in the central plateau; (b) P. purpureum production was 70 t/ha in the low areas, 50-60 t/ha in the high altitude areas, and 40 t/ha in the central plateau; (c) S. splendida and S. sphacelata production was 35-40 t/ha in the high altitude areas and 50 t/ha in the central plateau. Apparently, at low-altitude areas T. laxum and P. purpureum are more productive than in the high-altitude areas probably because of favourable high temperatures.

The distribution of harvests indicates that T. laxum production is steady during the 4 years of observations. P. purpureum, however, has a stable production pattern only in the central plateau and decreases with the age of the stands in the low- and high-altitude areas. Setaria produces in a generally constant pattern during the first 3 years, but there is a significant reduction thereafter.

In conclusion, the most productive grass is P. purpureum, but the decrease in its production of green material with time necessitates the planting of plots of different ages in the same field to maintain overall constant production. This is not necessary for T. laxum. The two Setaria can be planted to last 3 years; afterward, their resistance to grazing would make them ideal for grazing.

Compatibility with Legumes

P. purpureum can be easily grown in association with vigorous legumes that can tolerate competition such as Pueraria phaseoloides, Centrosema pubescens, and Desmodium intortum. The nutritive value of the mixture is quite reasonable and is superior to a pure stand of grasses. D. intortum has been intercropped with

S. splendida and S. sphacelata in the high-altitude areas. The mixture gave a 20% increase in fresh material yield as compared to pure Setaria. The protein rate also increased the CP content of the mixture to 6.7% in comparison to 5.6% for a pure grass stand. A mixture of Vicia sativa/S. splendida was achieved in part of the high-altitude area. For this mixture, there was no increase in green matter yield, however, the mixture was of high nutritive value.

Effect of Drought and Cold

Although T. laxum has good resistance to drought, P. purpureum requires more abundant precipitation. After a night frost in August in the high-altitude area (-6.9 °C at ground level) observations showed that 5% of the Setaria, 20% of the P. purpureum, and 70% of the T. laxum were seriously frost bitten.

S. splendida, which originates in high altitudes, is the most resistant grain to frost, followed, but not closely, by P. purpureum. T. laxum, which originates in the lower altitudes and humid areas of Central America, is naturally the most sensitive.

Rotation as a Means of Controlling Pseudomonas solanacearum

T. laxum, P. purpureum, as well as S. splendida fallow can be used in the biological control of bacterial wilt of potatoes caused by Pseudomonas solanacearum; the period between two successive croppings of potatoes is long enought to interrupt the biological cycle of the bacteria in the soil.

Distribution to the Farmers

The Ministry of Agriculture and Livestock Development multiplied the grasses in various centres in the different regions, then distributed them to livestock keepers, who in turn planted them on areas of approximately 0.5 ha each. The intension of the government was to enable farmers to produce enough feed to fill the deficits in the dry seasons. The government also wanted to discourage the livestock movement that is practiced in the dry season by putting at the disposal of the cattle keepers fodder species that can be cut and conserved for the dry season.

RESEARCH ON RECENT INTRODUCTIONS

Burundi attaches great importance to grasses and legumes that show resistance to drought. Additional species have been introduced and follow-up studies conducted by ISABU (Institute des Science Agronomique du Burundi). Notable among the grasses are: Cenchrus ciliaris, Cenchrus setigerus, Andropogon gayanus, Eragrostis curvula, Panicum coloratum, and for legumes: Stylosanthes guianensis, Mucuna utilis, Lablab purpureus. After some years of observation, three species were selected: C. ciliaris, P. coloratum, and S. guianensis. These species are under observation at ISABU.

Cenchrus ciliaris

The genus Cenchrus is adapted to tropical regions with seasonal rainfall and a prolonged dry season. It is found in the warm lowland parts of the country where annual rainfall varies between 350 and 1,000 mm. This species prefers light, well-drained soils.

Sowing directly in the field has proved to be the most useful method as long as large quantities of seeds are available, because the percentage of germination of these seeds is very low. More than 70% of the glomerule do not contain grain. In low-altitude areas, cenchrus produces abundant flowers and harvesting by hand is easy. However, seeds must be stored for at least 1 year to break the dormancy. The recommended rate of sowing in the low-altitude areas is 15 kg/ha for those sown in lines and 25 kg/ha for broadcast sowing. If precipitation is sufficient, germination takes place 1 week after sowing. C. ciliaris prefers light sandy soils, of white sands and clayey sandy red soils of the lower altitudes. Broadcasting gives good results on the condition that large quantities of seeds are used and the seed bed has been well prepared.

Cropping care should include eliminating all the bad weeds particularly during the first year when a vigorous, homogeneous grass population is expected.

Cenchrus can be used for grazing, hay making, or for ensiliging. As conservation is costly, _C. ciliaris_ is used mainly for grazing, particularly in the dry season, because it is one of the rare grasses that remain green for most of the year.

In low-altitude areas, yield varies between 10-12 t of green product per hectare per year in the first year. It is estimated that the Cenchrus could produce, annually, 7-8 t of green product per year for a period of 5 years.

C. ciliaris has so far proven to be the most appropriate grass in the dry areas of low altitudes. Its principal qualities are good resistance to drought, well accepted by the livestock, and vigorous growth makes it competitive during establishment. It produces great quantities of seeds that are easy to harvest, and it is easy to sow in lines. Its main disadvantages are that the seeds are not very viable and it is sensitive to blight (for production of fertile seeds).

Panicum coloratum

P. coloratum is adapted to tropical and subtropical climates with estimated rainfall ranging between 500-1,200 mm. It can survive the long dry season of the low altitudes. _P. coloratum_ does best in heavy, wet, fertile soils.

In theory, _P. coloratum_ can be sown by seeds, but because the production of seeds is practically non-existant in the low-altitude areas of Burundi, splits have been used extensively. It is, however, recognized that vegetative propagation is slow because 5 ha of nursery are necessary to plant 1 ha.

Various weedings are necessary to control unwanted grasses. _P. coloratum_ cannot compete against the weeds. Panicum should also not be grazed too soon as it takes time to take root and the animals can uproot them. _P. coloratum_ can be made into hay or silage but in Burundi it is used for grazing only.

In spite of some of its qualities, P. coloratum Makarikariensis cannot be recommended for the following reasons: it is unproductive during the dry season; it does not have any resistance and is easily infested by weeds requiring frequent weeding; the splits, which are slow in taking root, can be easily uprooted by grazing; and under Burundi conditions it is difficult to produce seeds.

Stylosanthes guianensis

S. guianensis was introduced as far back as 1953 in the eastern savanna and in 1970 in the low-altitude areas where it was used for improving the feed value of natural pastures that were poor in legumes. At 1,200 m altitude, in Mosso, Stylosanthes is well adapted to the climatic conditions and its performance is excellent. Since 1982, however, anthracnose greatly limits the growth of this species. But studies are now under way to find a way of solving this problem.

Research Priorities in Low Altitude Areas

In low-altitude areas, precipitation is low at less than 800 mm and the predominant sandy soils are limiting factors. What is required for this region is research on cultivars that are resistant to drought and adaptable to infertile soils and sowing methods that would help the cultivars to develop on sandy soils.

Since the establishment of Rukoko as a station, several strains of S. guianensis have been introduced. The Australian types did not seem able to adapt to the semi-arid conditions of the low altitudes. At the moment, the only promising variety seems to be the one originating from Mosso (ISABU station at 1,200 m altitude). It appears, however, that this type is a mixture of various cultivars whose "code" came up because of its resistance to anthracnose.

The plantation method for Stylosanthes in the low-altitude areas was done by tilling and harrowing natural fields, followed by broadcast or drilling with a mixture of Brachiaria ruziziensis.

At the Mosso ISABU station, planting is done by broadcast sowing of Stylosanthes in natural pastures followed by burning and the soil was not worked. This burning method is a fast, economical means of improving the rate of germination. Fire breaks the seed dormancy and, therefore, enhances seed germination. However, hot water treatment is recommended if fires are prohibited.

The relationship between soil/fodder/livestock/hoe and economic importance should be considered. Although Stylosanthes fruticosa performed very well in low-altitudes it is not very well accepted by livestock. S. guianensis, on the other hand, is quite acceptable, but, unfortunately, it does not adapt well in the region.

PRIORITIES AND RESEARCH STRATEGIES

One of the primary objectives of our research is to study the grasses and legumes existing naturally in the region and to improve the natural pastures by introducing grasses and legumes that can be adapted to the different regions. For this reason, a study is under way in three regions where livestock numbers are growing or where they are expected to grow in the near future.

The study involves first rational pasture management (proper utilization, planned grazing, and division into paddocks) and then the introduction of grasses of high nutritive value and legumes that can be mixed with these.

For 1984-85, there are plans to set up seed farms in four agricultural and veterinary research stations in the various geographical regions of Burundi. The seed will be of the following species: grasses - B. ruziziensis, C. ciliaris, Panicum maximum, Sorghum sudanese, and T. trianda, and for legumes D. intortum, Leuceana leucocephala, S. guianensis, Mucuna sp., and V. sativa.

A sanitary inspection plant will be installed and regular germination tests will be done and seed production techniques will evolve progressively.

The introduction of fodder trees and shrubs will also receive attention. Fodder hedges and bushes such as Prospopis chilensis, L. leucocephala, Chamaecytisus proliferus, Desmanthus virgatus, Medicago arborea, and many others may be used. Plant production nurseries will also be set up. These nurseries will include various species in accordance with experiments in progress and the arrival of ordered seeds.

SURVEY OF PASTURE RESEARCH IN MADAGASCAR

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Abstract *Malagasy are among the heaviest beef consumers in Africa. The major livestock are zebu cattle growing on native pasture and improved dairy cattle in the highlands. Seventy-two pasture species have been introduced; four extensively cultivated. Establishment of these pastures seems to be easier in pure stands than in mixtures. Trials show that animal production is high on grass pastures during the rainy season and on legume-based pastures as well in the first part of the dry season. Future areas of research will emphasize dairy small-scale farms and the pasture management of female and young zebu cattle.*

The annual beef consumption in Madagascar is 14.65 kg per capita (MDRRA 1980). This means that on the one hand the Malagasy are among the heaviest beef consumers in Africa; on the other hand, this shows the importance of cattle raising based on the abundant native pasture, although it presents some prejudicial characteristics on the development of cattle breeding. Research has been carried out over the past 20 years to improve the ruminant fodders. This paper provides a survey of the results of experiments and suggests future research priority areas.

Madagascar is an island situated between 11° and 25° S latitude. Its total surface is about 587,000 km^2. The main beef-cattle-raising areas are in the western and southern parts of the island including the Highlands.

There are two climatic seasons: the rainy season, beginning in November, is followed by the dry season, which begins between April and June and lasts for 6-8 months. The annual rainfall ranges from 400 to 2,000 mm. Vegetation is dominated by grassland dotted with forests.

The major livestock in Madagascar is zebu cattle, which are estimated at 10,281,000 head. There are about 1,730,000 goats and 795,000 sheep (MPARA 1982). These animals are mostly meant to produce meat, apart from their important social role. There are 60,000 head of European-like dairy cattle in the Highlands and in the middle-western regions.

Malagasy natural grasslands are characterized by their wide surfaces. They can be divided into four different communities: (a) In the far-west grassland, the principal species are Hyparrhenia rufa, Heteropogon contortus, and Chrysopogon serrulatus. (b) Down south the communities are dominated by H. contortus and Cenchrus ciliaris. (c) In the region commonly called the middle-west, the typical species are H. rufa and H. contortus. (d) The Highland grasslands are dominated by Aristida rufescens, Ctenium concinnum, and Loudetia simplex.

The annual liveweight gain for zebu catle on natural vegetation for grazing is around 40-70 kg (Granier et al. 1968; de Reviers 1970). The growing period coincides with the rainy season. The liveweight gain may reach 50-120 kg/head, but during the dry season, losses amount to about 20-60 kg/head and the young cattle are likely to die (de Reviers 1970).

Improved pastures are concentrated in the Highlands and the middle-west where dairy cattle are raised; milk production in these pastures varies from 1,300 to 3,500 L/lactation (Robert 1979).

PLANT INTRODUCTION

In the last 20 years, 72 pasture species have been introduced, 32 grasses, 32 legumes, and 8 cactus and browse species. These various species were tested in the four major pasture areas in Madagascar. Ten species or so proved to be the most adapted and productive. Tall grasses like maize, *Pennisetum purpureum* and *Tripsacum laxum* produce 18-22 t dry matter (DM) per hectare. Smaller grasses yield from 7 to 16.4 t DM/ha. It is worth noticing that native pastures may produce 13 t DM/ha (Rasambainarivo et al. 1983).

The highest yielding legume is *Stylosanthes guianensis* (6 t DM/ha). More recently, *Stylosanthes hamata* has been introduced, which is regarded as one of the most promising legumes in many ecological areas of the Island. For the dry south, *Stylosanthes humilis* was tested and proved to be well adapted; on fresh, dry-season highlands, *Desmodium* species are more recommended.

Four plants are used extensively, three grasses and one legume. The grasses are *P. purpureum*, *T. laxum*, and *Chloris gayana*; the legume is *S. guianensis*.

ESTABLISHMENT

Generally speaking, from the experiments conducted to date, establishing grasses is easier than establishing legumes, but the research work consisted mainly in determining the most efficient and quickest way of establishing legumes. This led to the study of the factors involved in the improvement of the germination rate of seeds first and then those involved in land preparation.

Improvement of Seed Germination

In our studies, the germination rates of *S. guianensis* and *S. humilis* seeds are low (Rasambainarivo and Razafindratsita 1976), so chemical and mechanical treatments of seeds were tried. The results indicate that these treatments are quite profitable and the germination rate can be increased, e.g., the germination of untreated seed of *S. guianensis* is about 20%, but after treatment it is up to 80%.

Land Preparation

Comparison of two methods of land preparation was made in three different regions (Rasambainarivo and

Razafindratsita 1980). One involved the introduction of legumes in native pasture by the sod seeding technique. The other involved the fully cultivated seed bed using ploughing and disking. The results indicate that the introduction of legumes in the native pasture in this manner is bound to fail 3 or 4 years later, due essentially to competition between the existing vegetation and the legume seedlings. This competition may last 3 or 4 years and the legume yields decrease from year to year.

However, in the case of a fully prepared seed bed, the legume production is high even in the 1st year (*S. guianensis*: 4-6 t DM/ha) and it remains so more than 5 years after depending on the grazing management. We have only used fertilizer during the establishment period just before sowing. We also tested the pasture persistence under these conditions when there was no more fertilizer applied in the following years.

Research on seed pelleting with Rhizobium is not yet well documented and, in most cases, we worked with species whose Rhizobium belong to the "cowpea" group. In future, it will be necessary to try inoculation, because after a trial conducted in the western part of the island, we noticed that the growing rates of legumes were much higher when they are sown on a formerly groundnut field.

Grass establishment is easier by sowing or in a vegetative way. When comparing the plant density of maize we do not find any significant differences between 71,400 and 128,500 plants/ha (Rasambainarivo and Razafindratisita 1979). In the middle west region associations were tried. No differences were found on dry matter yields of grass alone (*Chloris* or *Setaria*) or their association with *Stylosanthes* and *Siratro* (Rasambainarivo and Razafindratsita 1978). The legume-grass ratio dry matter basis is growing from the rainy season to the dry season.

CHEMICAL COMPOSITIONS

Chemical analyses were performed to assess the quality of species. The main conclusions can be summarized as follows with clipped samples (Bigot and Razafindratsita 1975; Rasambainarivo et al. 1983).

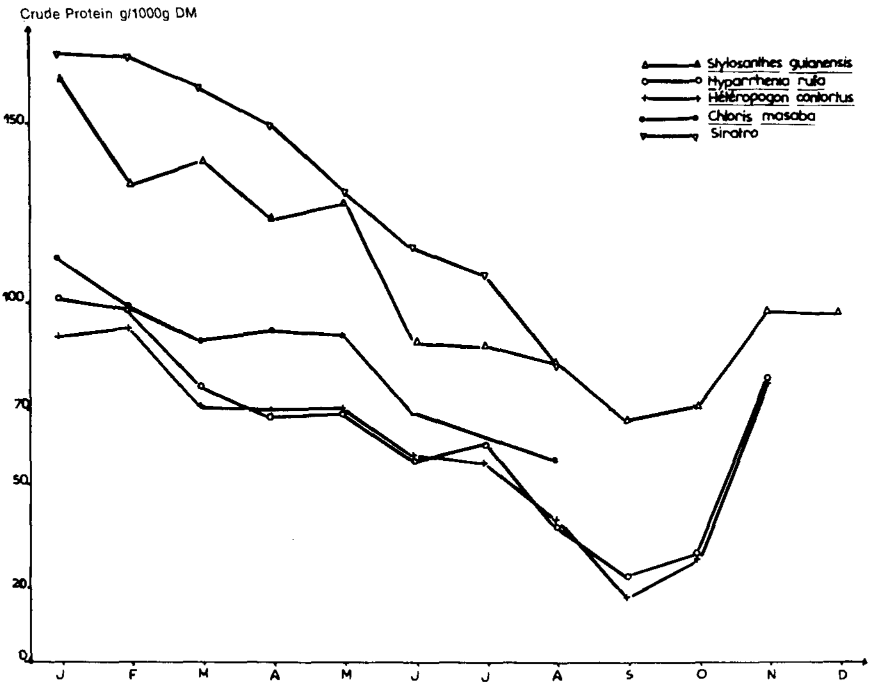

Fig. 1. Crude protein contents of pasture grasses and legumes.

Crude Protein (Fig. 1)

The crude protein content of the pastures decreases from January to September, after this it begins to rise. For grass species, the crude protein percentage is below the 7% level early in May for native pasture and 1 month later for C. gayana. It ranges from 10% in January to 2.4% in September for H. rufa. As for the legume species, their content does not show any important deficiency even in the dry season. Maximum percentage is reached in January at 16.8% with Siratro.

Phosphorus (Fig. 2)

For all the species, phosphorus content is less than 2% year round except for some samples of Siratro in the rainy season.

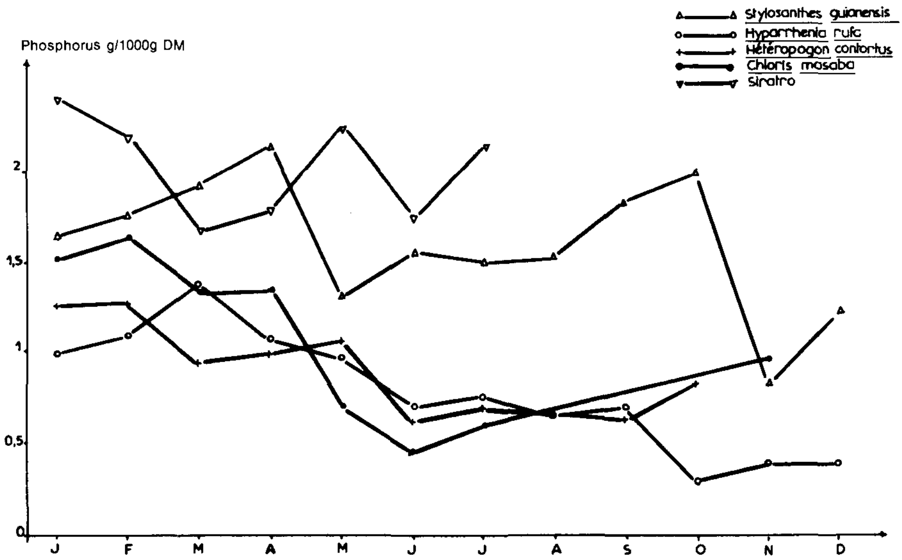

Fig. 2. Phosphorus contents of pasture grasses and legumes.

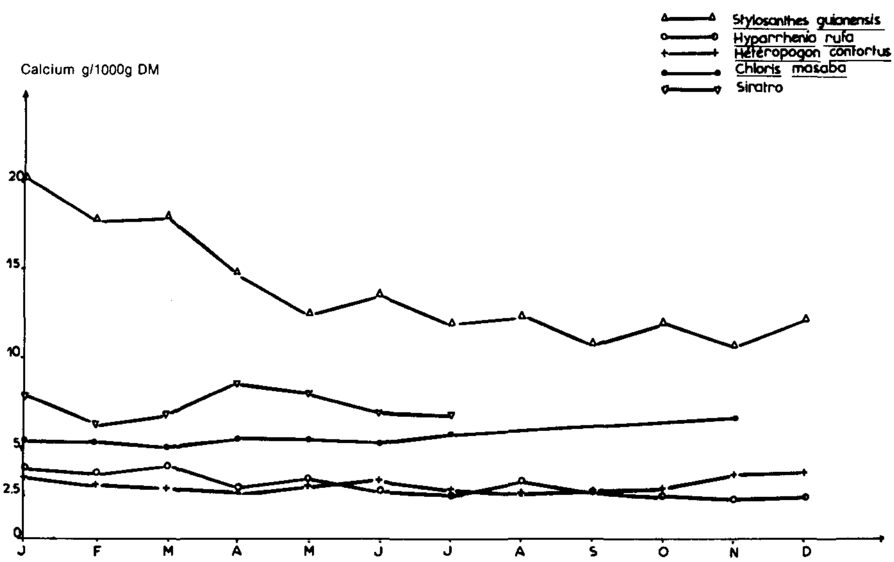

Fig. 3. Calcium contents of pasture grasses and legumes.

Calcium (Fig. 3)

The calcium amounts were considered sufficient to meet the animal requirements in the rainy and dry seasons. This content is usually constant at 2.8% for native species.

GRAZING MANAGEMENT AND ANIMAL PRODUCTION

The major cattle nutrition problem in Madagascar is experienced in the dry season. Pasture evaluation trials and traditional beef management practices indicate that the rainy season pasture is sufficient and has an adequate nutritive value for growth.

Experiments were undertaken to assess beef cattle production on pasture with different stocking rates. Usually, different fixed stocking rates were compared using the continuous grazing method. Six trials were conducted in three areas (Table 1). The main conclusions are that legume-based pasture may be stocked with from 1 to 11 animals/ha. The liveweight gains range from 0.136 to 0.430 kg/day (equivalent to 40 to 280 kg liveweight gains/ha). The main factors affecting animal production are stocking rates and the experimental season. So, by increasing the stocking rate we increased the animal output (Fig. 4). With 2 animals/ha, the gain is about 50 kg/ha but with 11 animals/ha the gain reached 200 kg/ha, even if the individual daily gain decreases from 0.220 to 0.180 kg. Trials, however, conducted in the western region show a very high liveweight gain on a grazed sorghum pasture. Daily individual gain reaches 0.688 kg and the liveweight gain per hectare is about 603 kg when stocked with 12 animals/ha (Fig. 5).

We have also tried the use of maize silage for zebu cattle fattening. The daily liveweight gain rose to 0.720 kg but the silage must be supplemented with 1 kg cotton seed-cake/animal/day (Rasambainarivo et al. 1978). Each hectare sown with maize forage permits a gain of about 1,100 kg liveweight.

All these results indicate that legume-based pastures are very promising during the rainy season and the first part of the dry season (until Septem-

Table 1. Liveweight gains from Zebu cattle grazing artificial pastures in Madagascar.

Pastures (cultivated areas)	Experimental management	Stocking rates (animals/ha)	Duration of experiments (days)	Results		References
				Daily mean gain (kg)	Gain/ha (kg)	
Chloris gayana + *Melinis minutiflora* + *Centrosema pubescens* + glycine + *Stylosanthes guianensis* (1 ha)	"Put and take"	4			286	Razakabaona (1969)
Stylosanthes guianensis + *Chloris gayana* (6 ha)	Continuous grazing	2	71 (May-Jul)	0.430	61	Rasambainarivo and Rakotozandrindrainy (1977)
		2		0.275	39	
		4		0.331	94	
		4		0.165	47	
Stylosanthes guianensis + *Siratro* (8 ha)	Continuous grazing	0.9	137 (Mar-Aug)	0.350	43	Rasambainarivo et al. (1983)
		1.8	82 (Mar-Jun)	0.266	39	
		2.8	61 (Mar-May)	0.328	57	
Stylosanthes guianensis + *Siratro*	Continuous grazing	3	125 (Feb-Jun)	0.245	81	Rasambainarivo et al. (1983)
		6		0.136	100	
		9		0.174	197	
Stylosanthes guianensis + *Siratro* + *Pennisetum purpureum*	Continuous grazing	4	125 (Feb-Jun)	0.180	78	Rasambainarivo et al. (1983)
		7		0.202	177	
		11		0.204	282	
Sorghum sp. (7.5 ha)	Continuous grazing	2.8	70 (Sep-Nov)	0.658	103	Rasambainarivo et al. (1983)
		5.2		0.631	210	
		9.0		0.522	286	
		12.5		0.688	603	

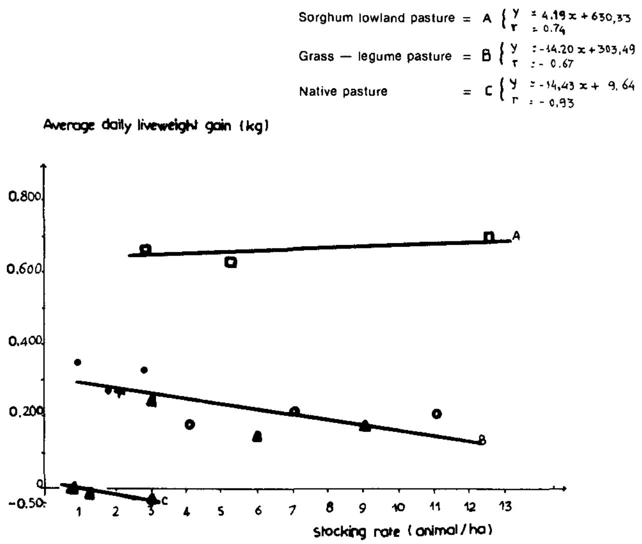

Fig. 4. The relationship between average daily liveweight gain and stocking rate for three pastures in the western region of Madagascar.

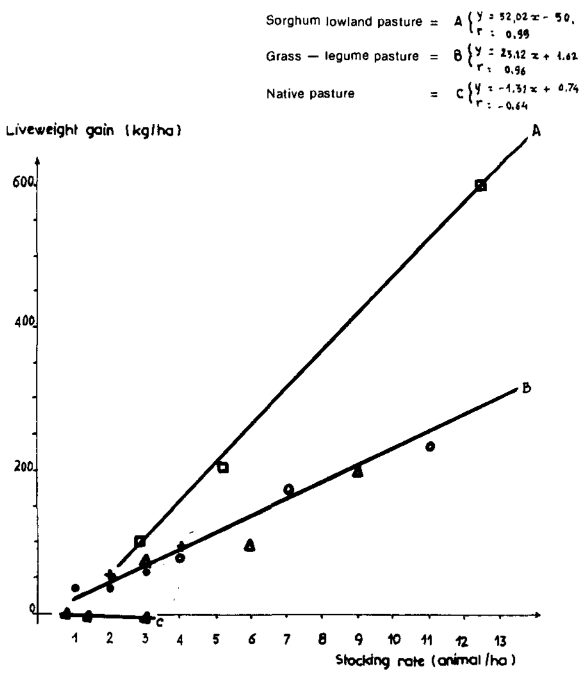

Fig. 5. The relationship between stocking rate and liveweight gain for three pastures in the western region of Madagascar.

ber). They permit some appreciable gains for zebu cattle, and the tall grass pasture, fresh or silage, may be used for beef fattening.

RESEARCH METHODOLOGY

The main purpose of a pasture is to provide food for grazing animals. Therefore, the final value of a pasture is to be expressed in terms of animal production. Our research methodology is then determined by this objective and the various local conditions. Because of a lack of qualified staff, a pasture research team was only formed after 1970.

The history of pasture research in Madagascar can be divided into three periods: from 1960 to 1973, studies were focused on native pastures, the way to improve them by management and plant introduction; from 1974 to 1977, plant introduction was carried on with establishment trials; and, finally, since 1978, we have undertaken some small regional screening trials along with the evaluation of pasture and silage through animal performance, measuring mainly liveweight gains. All these studies were performed in experimental stations and centres, and plant introduction is the result of interinstitution exchanges.

For clipping trials, the plot areas range from 24 to 50 m^2, where, as with grazing experiments, cultivated areas can reach 10 ha. In this case, management is in the form of continuous grazing with fixed stocking rates. The starting weight for zebu cattle is about 250 kg and experiments last 2-4 months.

FUTURE RESEARCH PRIORITIES

We have now some information on native pasture productivity and its limits and some data about introduced species that are well adapted. In the future, emphasis will be put on two areas: a better understanding of pastures and their management techniques for the dairy smallholdings, and the establishment and management of pastures to increase the female conception rate and encourage a more regular growth of young zebu cattle.

Research will be conducted in experimental stations and centres, but we are fully aware of the importance of on-farm trials. Sectorial and multidisciplinary research will be necessary at both the national and the international levels.

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REVIEW OF RANGE AND PASTURE RESEARCH IN BOTSWANA

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Abstract *Although the Animal Production Research Unit's (APRU) basic research for 1970-80 has established the benefits to be obtained from an improved management system that depends upon controlled stocking rates, access to water, and fenced paddocks, little is still known about the interrelationship of traditionally kept cattle and the natural range. APRU (Ministry of Agriculture, Botswana) uses conventional parameters of livestock productivity per head that show ranch cattle superiority over the communal herds.*

A minimum acceptable standard of management will improve animal productivity. But 90% of the national herd is kept communally under traditional systems and when looked at from the point of view of productivity per hectare of land, "production" being the total benefits the herd owner obtains, then a very different picture emerges. Milk production and draft power are both important contributions from the herd, and when added in terms of energy derived from grazing to the already slanted stocking rate then the productivity on a per hectare basis becomes reversed. However, the facts of rising cattle populations, together with opening up of more water points in the western Sandveld, and the realities of the commercial aspects of the Tribal Grazing Land Policy (TGLP) (1975 White Paper) all point to the need for a revision of priorities. The Ministry of Agriculture has responded to paragraph 24 of the TGLP in which responsibility for controlling stocking rates and management of the communal range is directed to cattle owners whose tenure will not change.

Communities are being sought whose rangeland can be identified for initial improved management approaches. The Ministry Fodder and Forage Committee has been established and good liaison with APRU and regions exists. By 1984 a Botswana forage and pasture seeds multiplication program will have begun, and it is hoped that at least one further pasture research officer will be appointed into APRU.

Botswana, covering an area of 582,000 km^2 is situated in the middle of the southern African plateau with a mean altitude of 1,000 m above sea level. It is usually described as saucer-shaped with marked topographical features mainly in the east along the line of the Hardveld, where soils capable of supporting crop production in favourable rainfall years are found. This eastern swath varies in width from 50-150 km. The central basin is covered by significant depths of Kalahari sand. In the northwest, the Okavango delta provides a separate ecosystem. The country extends from 16°S to 27°S and from 20°E to 29°E.

Rainfall averages 475 mm/year, but varies in total by as much as 50-70% from year to year. The rainfall is highest in the northeast at 650-700 mm (varies from 400-1,200), falling through the central areas to 400-550 mm (200-850), to a minimum of 150-200 mm (0-400) in the southwest. Monthly precipitation gives little guide to effective rainfall as it is considered that 10 mm or less, unless following good previous rains, never effectively penetrates. Thus, 50% of monthly precipitation or more may be ineffective. Evapotranspiration is high from December to March. Seasonal commencement and end of rains are equally unreliable, and early planted crops are just as likely to suffer from a drought period as late planted intentions never getting established.

The country may be divided into three main ecological zones: the better-watered Okavango of the northwest, the main Kalahari system, and the eastern Hardveld. The Hardveld is further subdivided into the northern deciduous forests, the north and central Mopane veld, and the southern Acacia/Combretum complex. This is of course an oversimplification. Weare and Yalala in 1971, for example, refer to vegetation plotting of the east and northeast by Henkel in 1931, Pole-Evans in 1936, Irvine in 1945, and Adcock in 1953. De Beer in 1962 plotted 26 different vegetation types grouped within six physiognomic definitions. Weare and Yalala produced 29 vegetation types grouped under nine physiognomic definitions. Since then, Blair-Rains and McKay produced in 1968, "The survey of the Northern State Lands," and Blair-Rains and Yalala a "Survey of the Central and Southern Lands" in 1969. Aerial photography has been used since 1947, and in 1963, 103,600 km^2 of eastern Botswana were surveyed for land resources by Bawden and Stobbs.

They recognized 29 land systems and divided these into nine categories for agricultural potential. The Range Ecology Unit has, since 1970, mapped fluoristically most of the major zones of the country, and there is good background knowledge of the tree and grass cover. Van Ransburg (1970) identified a range of potentially useful indigenous legumes and put down a range of trial species at Morale.

In 1973, the Land Utilization Division of the Ministry of Agriculture of Botswana established recording sites on eight of the Animal Production Research Unit (APRU) ranches to monitor (a) increase in bare ground, (b) encroachment of woody shrubs or trees, and (c) detrimental changes in botanical composition of the lower layer.

Methodology was a compromise from Walker (1970) to a modified form of Parker's three-step method used by the U.S. Department of Agriculture Forest Service (1951). A recent consultancy has recommended a change in methodology that is under review (Prince 1982).

By this time, APRU was appreciating the importance of defining eroded or badly degraded areas. Range monitoring has been continuous since 1973, noting that all previous surveys had not identified trends in range succession and regression. To this end an assessment was made in 1975 to identify a simple indicator that could be used for categorizing Botswana's grazing. This was noted under "Re-Seeding and Renovation" (APRU 1975). Other relevant publications are "A Hand Book of Common Grasses in Botswana," by David I. Field (1976), and "A Hand Book of Botswana Acacias," by J. Timberlake in 1980.

SURVEY OF RESEARCH METHODOLOGY AND PRIORITIES 1964-76

The Morale Research Station was established in 1931 on the advice of Professor R. Lindsay Robb under Sir Russel England. It is situated south of Mahalapye 23°S, 27°E, climate, soil, and vegetation being representative of East Botswana.

Cattle weight records ~~and~~ botanical reports were begun in 1951. Various grazing systems were imposed to measure live weight response and effect on veld, and different stocking rates were applied. A cleared trail was added in 1953. In 1964, the methodology of botanical analysis was changed. The trails followed adjacent territory interests in continuous grazing vs. rotational grazing vs. short-duration grazing. In 1964, it was not considered possible for the design pattern to measure any changes satisfactorily.

However, McKay stated that there were no large or obvious changes to evaluate, but it was considered justifiable to continue botanical sampling, and a number of questions remained unanswered: (a) influence of stocking rate and rainfall on yield and botanical composition, (b) effect of additional supportive irrigation to counteract rainfall deficiencies on yield of herbage, and (c) addition to nonprotein nitrogen (NPN) supplementation to winter nutrition.

The changes in species composition was noted between the various stocking rates but, because of lack of homogeneity within the paddocks, no significant conclusions could be drawn. These were summarized by McKay in 1968 who recommended improved methodology and a spread of investigation across other vegetational types. Nine stations were set up within the APRU ranches during 1972.

In 1976, APRU assessed conclusions drawn from previous research work to try to identify those variable factors in the natural rangeland that had the greatest effect on animal productivity and summarized a series of conclusions and recommendations:

(a) Deficiency of phosphorus in the pasture was endemic and the benefits of supplementation proven.

(b) Low levels of crude protein and dry matter digestibility (DDM) in herbage in the dry season varied seasonally.

(c) Only breeding stock seemed to respond economically to supplementary NPN when fed in the dry season, but total DDM ingested might be an inhibiting factor at set stocking rates.

(d) There remained the need to determine nutritive value of the range of desirable species and methods of encouragement, including bush control.

(e) It was recognized that evaluation of grazing systems is a long-term program but that detailed monitoring and measurements have to be continued.

(f) Range and livestock monitoring of the western state lands started as a result of the absence of production data from the area and the assumed fragility of the ecology and signs of overgrazing around adjacent cattle water points.

It was known that by careful control of grazing pressures, better species could contribute. The need to widen the scope of investigation was evident, and by 1977 it was concluded that the possibility of introductions, legumes, grasses, and fodder crops, into the system was a major need for investigation. Range improvement was considered possible under controlled conditions and the role of introduced reseeded legumes had to be thoroughly researched. The economics, feasibility, and adoption prospects were all aspects that had to be considered in their proper place, and initially, response to fertilization was investigated for all introduced species.

However, although acknowledged that the cyclical disasters of stock losses due to drought have been rapidly replaced in the past, the possibility of a degraded range modifying or even preventing this recovery in the future is too dangerous a theory to accept complacently. The importance of meaningful research into pasture species and fodders for all eventualities has now become, therefore, an accepted tenet of animal and range research. But the spectre of drought and drought relief measures hovers in the minds of some planners, and several consultants over the years have referred to fodder bank reserves of drought resistant species being set up.

These suggestions have not so far been taken up by government. The history of pasture research to date has to be seen, therefore, against the noncommitment of local thinking and the probability that individual effort will produce individual qualitative and quantitative biomass bonuses that will initially be slow to be generally adopted. It is still true that "shortage of grazing" is seldom perceived as the main problem of "cattle management."

GENERAL SURVEY (BEFORE 1977)

Before 1976/77, research work had concentrated on investigations into range productivity and botanical composition of the natural sward. The broadening of this approach only since 1977 to include pasture research has to be viewed against the background of the political history of Botswana as a reservoir of migrant labour and beef cattle. The country remains essentially an extensive beef-producing rangeland.

Yet, although it is still recorded as one of the least densely populated countries of the world, the localized skewed population increases within the variable ecosystems have created pressures upon the natural resource capability that can no longer be alleviated by time-honoured migratory processes during the cyclical periods of drought that recur with indeterminate regularity. The impact of early settler methods of simple forms of conventional "commercial production" had no impact upon the indigenous peoples. To both groups the variability of seasonal rainfall created an attitude of conservative extensive range usage with seasonal transhumance, destocking, or agistment, relieving localized drought stress conditions in bad years.

Intensification was not a word familiar to tribesmen or settlers. Dry-season water availability finally determined grazing pressures and there has been a constant move westward by larger herd owners into the more fragile Kalahari ecosystems, with overt pressure on government to sanction more borehole drilling in these western rangelands since the 1950s. These moves were accelerated by increasing land pressures in the areas of the eastern Hardveld where a heterogeneous form of mixed farming has been practised unconsciously by the rural peoples for many years, due to profiles permitting surface water accumulation, higher overall rainfall averages, and soils at least marginally capable of supporting an arable crop.

This area also carries 70-80% of both human and livestock populations. Traditionally, chiefs delineated arable and grazing lands. There is no evidence yet that land hunger as such is a recognized problem, but the conflict between land allocation as between arable and grazing has become a reality, and in some districts has become acute. These eastern Hardveld areas contain most of the potential arable soils of the country. Since enactment of the Tribal Lands Act of 1968 and amendments of 1969 and 1970, Land Boards have taken over the powers of land allocation. Early settler uptake of freehold blocks brought no boost to arable methods, which were designed primarily to provide self-sufficiency, so far as possible, in favourable years. Climate and soils in general militate against achieving highly profitable levels of production of cash-earning grain, pulse, and oilseed crops from dryland farming.

Nevertheless, along the eastern Hardveld there is a long history of annually ploughing part of the allocated land area by the rural households, and comparisons between 1975 and 1982 aerial photography show considerable opening up of arable lands in areas that were previously available as grazing.

During the late 1960-70 period, the government also became aware of the increasing magnitude of the problem of uncontrolled opening up and abuse of watering points in the fragile Kalahari bush savanna and the increasing pressures (localized at first) of rising cattle populations competing with more lands being allocated for plowing in the eastern Hardveld areas. Thus, the policies known as LDP 1 and TGLP evolved.

LDP 1 -- Livestock Development Project

The first Livestock Development Project (LDP 1) included a pilot establishment of a ranching block in the western Sandveld financed jointly by IDA (International Development Agency) and SIDA (Swedish International Development Authority) in the Ncojane area, with individual ranches to be leased to cattle owners and a SIDA Range Ecology team to monitor influences from 1975.

The area has been subject to monitoring of cattle productivity levels by APRU, and two study areas have been used to test stocking rates and grazing systems in what is known to be a sensitive environment where cautious management is needed to sustain production.

The studies confirmed that in this kind of fragile environment stocking rates are critical, and even spread of water reticulation vital. Tentative suggestions included 20-25 ha/livestock unit (lsu) for Schmidtia-Stipagrostis range, and 30-35 ha/lsu for the poorer Aristidia-E. pallens type, which is very vulnerable. With few exceptions all ranches show serious overgrazing around water points, and concern is for degradation to become irreversible on the poorer range. The reports all confirm the need for extreme caution in opening up this fragile ecological zone.

TGLP -- Tribal Grazing Land Policy

The White Paper was produced in 1975. Its objective was to make grazing control possible and at the same time increase cattle productivity. Also, the intent was primarily intended to safeguard the interests of the large percentage of tribesmen with few or no cattle.

There was concern for control of overgrazing and decline in productivity, and zoning was proposed, regionally, to set aside certain areas for "commercial leasehold blocks for ranching by bigger herd owners" and "reserve" areas to accommodate future expansion needs of the general traditional herd, with its wide variety of herd sizes. A report of a consultancy by S. Sandford was published in July 1980, which highlighted some of the major concerns about the implementation problems of the TGLP.

APRU (Range Research) continued to evaluate three specific areas (1970): (a) measurement of animal productivity from the natural range, (b) measurement of what the natural range could supply to the grazing animal, and (c) measurement of the effect animal productivity had on the natural range. The high selectivity for crude protein by grazing stock was also evident as well as the consistently good levels of crude protein in some of the indigenous grass species.

APRU had by now established a scattered spread of ranches throughout the country with a standardized "minimum acceptable level of management" that was largely standard commercial practice, and claimed levels of animal production were significantly higher than those recovered from traditional cattle posts. There was considerable variation between ranches, however, and considerable variation between figures of dry matter production per hectare from the range (ILCA report (1981), Bostwana Working Document No. 6) (LEU Vol 2 (1982), "Production and Nutritional Value of Range Forage") (Table 1).

There had been a full recovery from the drastic fall in the cattle population due to the low rainfall cycle of the early 1960s and the annual increase was moving upward again at 4%/year (Table 2). Although it was appreciated that the implementation of the TGLP policy was likely to be slow, the conventional thinking clung to the belief that considerable improvement in livestock productivity would be possible if distribution and management could be manipulated, and the exodus of the larger herds from the overstressed eastern grazing areas would relieve this pressure.

Table 1. Ranch cattle compared to communal herds.

	Ranch	Cattle post
Calving (%)	74	46
Mortality	8	10 (12-14)
Calf weight at 7 months (kg)	178	123
Calf weight at 18 months (kg)	278	207
Cow productivity at 7 months (kg)	120	51
Cow productivity at 18 months (kg)	188	86

Table 2. Livestock population figures.

Year	Cattle ('000)	Sheep	Goats
1965 (after 4 years drought)	1481	125335	335134
1975	2564	420000	1400000
1983	2818	164700	782800
(Commercial herd	410700)		

Nothing of the sort has taken place, and the situation in the communal areas becomes more acute rather than being alleviated. There was also a tacit naivety in the assumption in the White Paper, namely that (a) fencing would provide the means to increase productivity, and (b) tenants would have the will to adopt improved management and adhere to recommended stocking rates.

Subsequently, the policy known as ALDEP (Arable Lands Development Programme) in 1978/79 followed as a means of providing practical assistance to the smaller, least-advantaged, rural households who would not benefit by the broad implications of TGLP. The ultimate aim was self-sufficiency in staple food-grain productions, increased productivity being achieved through the provision of a number of grant-aided packages to the arable farming families. There was a total preoccupation with the constraint of inadequate draft power, and after great debate the late acceptance of a post for a pasture/fodder production officer was largely conceded on the concept that improved nutrition of the working oxen was the objective, the post was still being debated in June 1981. The officer finally was appointed in 1983. By this time, the Integrated Farming Pilot Project (IFPP) had already been working on the basis of a need for more realistic integration of crops and livestock into what effectively is a mixed farming situation, for 2 seasons, principally on the screening of a variety of species potentially useful for introduction into the traditional systems (see the section on Assessment of Investigation Needs).

Recent evaluations of both TGLP and ALDEP have coincided with the current cycle of drought, and a number of internal seminars and workshops have become increasingly concerned with environmental conservation and drought strategies. In a country beset with periodic droughts, cyclical yet unpredictable, of varying degrees of impact upon the rural populations according to the severity of water shortages compared to needed demand, it is inevitable that drought strategies at least look at alternate fodder bank provision. A number of consultancies have referred to this matter in the past. Although drought-resistant species capable of accumulated production that would contribute significantly to such a fodder bank in times of stress are not usually associated with pasture research, it has to be noted that more work needs to be done in this field (there has been no formal reaction to consultancy recommendations on this subject).

Furthermore, the work already done does indicate that there is scope for investigation into quantitative bulking-up of local fodder banks of more conventional forage species planted as a rain-fed crop with supportive irrigation from any of a number of stock watering boreholes. Experience here suggests that the crop would have to be early planted to ensure against the failure of mid-season planting rains, as well as the early cut-off of the whole season.

It is significant that in spite of the proliferation of boreholes during the last 30 years this fact still holds true. Water determines the distribution of livestock populations except in times of extreme drought, when the disasters of insufficiency of herbage under conditions of minimal precipitation are felt most severely in the most heavily populated areas of the eastern Hardveld. Drought is a cyclical reality, however, and conditions the thinking of most political planners and aid donors.

It is still possible in the western Sandveld to find tracts of undergrazed land empty because of lack of water. In the east, such pockets are now small, but still exist. Large tracts of the eastern areas have been denuded temporarily of stock by their owners in the present circumstances by complete removal of edible forage.

Notwithstanding this deliberately painted picture there is scope for improvement of levels of productivity from any given unit of land, in any given season, but the degree of variability is high due to the extremes of differentiation of seasonal rainfall patterns. Also drought strategies are relevant. Annual, even monthly means of rainfall expectations have no relevance under the circumstances.

Much has been learned in the attempts to improve reliability of performance of arable cropping, and it is here that the relevance of improvement of fodder-bank potential begins to become meaningful. Enough has now been done to justify the claim that given the will, and the seed, any year can be made to produce a significant level of fodder for the ruminant animal over and above that to be expected from the natural range. The significance of variability of rainfall makes it impossible to predict which particular methodology will pay off best in any given year, except where there are guarantees of irrigation, and, hence, the need that was foreseen to explore a variety of options both of species and of times of planting as well as annual, biennial, and perennial. Methods of conservation and utilization best suited to the differing constraints of livestock owners also need to be answered, and it is unlikely that one single, simple set of solutions will evolve.

Size of herds, herd structures, family labour availability, family wealth, size of arable holding, and area customarily cultivated each year, all will influence decision-making.

METHODOLOGY IN PASTURE RESEARCH (AFTER 1976)

Transfer of an FAO pasture research range officer to the APRU team enabled a review of past work to be undertaken and the practicalities of seed availability to determine a future program. From a long checklist (180 spp) of indigenous Papilionoidea and herbage legumes, seed was collected from 12.

Of the grasses, Cenchrus occurred locally, and Panicum coloratum and Eragrostis curvula were available commercially. Urochloa mosambicensis locally occurring was cultivated in Australia. It was decided to exclude

Chloris guyana because of lack of drought tolerance. But the ALDEP pasture research officer will probably reassess Rhodes grass in the northern areas of Kasane.

Initial investigation consisted of nursery-plot establishment with evaluation of quality characteristics and further seed collection. Siratro established by Van Ransburg (1970) had survived and seed was used in compatibility trials with Cenchrus ciliaris and E. curvula using basal dressings of 400 kg/ha single supers + split three levels of nitrogen. Other survivals: Rhynchosia sublobata was still growing but failed to set seed. Only isolated plants of Neonotonia wightii survived.

Leucaena

Leucaena glauca is a leguminous shrub or small tree which has long been recognized as a valuable drought resistant fodder plant (Arnold 1934). Interest has recently been revived in Malawi (FAO), although trials in Zambia have been less encouraging.

Seed of four Leucaena cultivars, Peru, Cunningham, Hawaiian cross, and Hawaiian giant, were obtained from Malawi. Plots of each species, 5 x 5 m, were planted in rows 1 m apart with 10 cm spacing between plants. Compound zincated fertilizer 2.3.2 at the rate of 400 kg/ha was applied. The plots were sown in mid January and germination and establishment were good, but subsequent growth within the plots was very uneven. By mid February plants were up to 4 cm high, by mid September individual plants were 50 cm high, but the majority only 15 cm. Hawaiian giant and Cunningham are the cultivars that have made the best growth. All cultivars were slightly scorched by light frost in June and July.

Larger plots of 15 x 8 m were sown on a separate site at the same row and plant spacing, and fertilized with single superphosphate (250 kg/ha). Germination was good, but in spite of weeding, all plants had died by mid April. The soil at this site was a sandy loam with a pH of 4.9. Although all seeds were inoculated with the correct rhizobium strain at sowing, nodulation of Leucaena has not been observed. In preparation for further trials the four cultivars have been established in pots under greenhouse conditions for planting out at different sites.

Cenchrus ciliaris

Farm practice for C. ciliaris on the Research Farm at Content is to seed with a fertilizer distributor at the rate of 4 kg/ha. This technique was used in an attempt to establish approximately 2 ha of the grass. A basal application of 250 kg/ha of single superphosphate was applied and seed sown at the beginning of January.

On block 2 of this trial, a 3 x 3 trial to investigate the effect of P and N on establishment and growth was laid down. Treatments were: P_0, no phosphate; P_1, 200 kg/ha single superphosphate; P_2, 400 kg/ha single superphosphate; N_0, no nitrogen; N_1, 150 kg/ha LAN; N_2, 300 kg/ha LAN. There were four replicates in a randomized block design with a plot size 5 x 5 m. Germination and establishment were good but again weed growth was excessive and no evaluation cuts were made.

Differential rates of LAN were applied to established swards of Cenchrus on three different sites on the research farm. Treatments were single applications of LAN at the rates of 80, 120, 160, 240, and 320 kg/ha applied at the end of January. A randomized block design with three replicates per site and a plot size of 5 x 4 m was used. No significant difference in the results of an evaluation cut taken in April was shown, although an increased response up to the application of 160 kg/ha on site 3 was obtained (Table 3).

Table 3. Cenchrus ciliaris yield of DM (kg) with differential N fertilizer application (plot 0.002 ha).

Treatment	Site 1	Site 2	Site 3
N_1	16.6	15.6	27.3
N_2	21.0	18.0	29.6
N_3	15.3	22.0	40.0
N_4	19.6	24.3	29.6
N_5	19.0	24.6	31.6

Increasing Yield and Quality of Natural Grasslands

An experiment was conducted on Morapedi Ranch to study the effects of applying fertilizers to natural grasslands. The treatments were nitrogen (N) in the form of urea at 0, 50, 100, and 150 kg/ha; phosphorus (P) in the form of single superphosphate at 0 and 33.2 kg/ha; and potassium (K) in the form of muriate of potash at 0 and 26.2 kg/ha.

All combinations, 4 x 2 x 2, were arranged in a randomized block with two replications. The nitrogen was applied in three dressings: the first, together with the phosphorus and potassium on 11 November 1976, the second on 14 December 1976, and the third on 30 December 1976. The plot size was 10 x 10 m and the area harvested measured 8.3 x 8.3 m.

No weather data other than rain were recorded, but the following are estimates based on data from Sebele weather station: temperatures at noon were, in general, above 30 °C; daily loss of moisture was on average 8 mm.

The yields, expressed as oven-dried material, are shown in Table 4. Phosphorus and nitrogenous fertilizer treatments produced highly significant effects, but not potassium, so that the data in Table 4 show the average response of the grass to nitrogen in the presence or absence of phosphorus. All responses shown in Table 4 are significantly different from the control (N_0 P_0) at $P < 0.01$.

Table 4. Mean response of grass to nitrogen in the presence or absence of phosphorus (kg/ha oven-dry material).

	P_0	P_1
N_0	1020	1386
N_1	1578	2026
N_2	1579	2696
N_3	1558	3148

Note: Standard error of a difference between two means = 98 kg.

After harvesting, representative samples were analyzed for the following constituents: crude protein (CP), total phosphorus, and in vitro digestibility. The crude protein percentage increased as the amounts of nitrogen fertilizer were increased. None of the other fertilizers had any significant effect on the CP%. The phosphorus application increased total phosphorus content in the grass from a mean of 727 ppm, to a mean of 1,548 ppm. None of the other fertilizers had any significant effect on the phosphorus content. The differences between the grass treated with phosphorus and the untreated grass are all significantly different.

In vitro digestibility percentages are shown in Table 5. The nitrogen applications alone increased the digestibility percentages. In particular, grasses receiving the N_2 and N_3 treatments were significantly higher than the digestibility percentages of the N_0 treatment.

The fertilizer treatments brought about changes in the botanical composition of the plots. From each plot, 5 x 1 m^2 quadrats were cut just before harvesting. A botanical analysis on this material revealed that it was made up mainly of the following species: *Brachiaria nigropedata*, *Anthephora pubescens*, *Schmidtia pappophoroides*, *Eragrostis* spp. together with small quantities of unidentified grasses and nongrass species (forbes).

The *Eragrostis* spp. and the grasses grouped with them increased in weight as the quantity of nitrogen was increased. This increase was significant and rapid.

Table 5. Mean digestibility percentages in relation to N treatments.

N Treatment	Digestibility percentage
N_0	41.64
N_1	44.50
N_2	48.54
N_3	46.73

Note: Standard error of difference between two treatment means = 2.35%.

It would appear that there is an interaction between nitrogen and phosphorus fertilizer in the case of Eragrostis species, response being limited in the absence of the latter element. A similar result occurs with B. nigropedata. The growth of A. pubescens is depressed by the higher levels of nitrogen, whereas S. pappophoroides is not depressed by the higher levels. Experiments will be done on Sebele and Morale stations in addition to that at Morapedi in the coming year.

From 1979, further work was focused on a few specific legume species, Siratro and Stylos, and a comparison of various cultivars of C. ciliaris, together with some important and significant measurements of the response of Cenchrus and Eragrostis to various levels of application of N and P. APRU has always acknowledged that 92% of the cattle in Botswana are maintained under traditional systems of management, and a shift of emphasis has been made since 1979 to accommodate the special problems of the community-based livestock populations.

Siratro

For rangeland improvement purposes, attention has been concentrated on Siratro, Leucaena, and the genus Stylosanthes. A plant introduction nursery was established at Sebele in 1971 and one at Mahalapye in the following year. Details of these introductions and the yields obtained were given in APRU (1979). Cenchrus and Siratro plots have been maintained and their yields recorded.

It was noted in APRU (1980) that some success had been achieved with Siratro at Musi, Morale, and Tsetseku. At these three ranches the legume was sown in strips within cleared lands. Persistence of the legume has been good at both Musi and Morale.

Plans were made to replicate this work at other ranches, but it was decided to make preliminary small-scale sowings. A series of exclosures, either 625 or 250 m^2, were, therefore, established on the sites shown in Table 6.

Table 6. Sites of sown fodders on APRU ranches.

Site	Number of exclosures	Location East	Location South	Rainfall 1 Sept. 81 - 31 Mar. 82
Sunnyside	2	25°44	25°06	442
Masiatilodi	2	25°00	25°02	322
Seleka[a]	1	27°45	23°02	355
Lesego	1	27°19	21°55	61
Tsetseku	1	23°10	20°10	234
Morale	2	26°50	23°12	335
Masama	4	25°25	23°50	266
leupane	1	27°00	22°35	147
Nata	1	25°57	20°00	na[b]
Dukwe	1	26°35	20°36	na
Maitengwe[a]	1	27°25	20°40	na
Matlolakgang	2	25°10	23°54	351
Impala[a]	1	27°35	21°10	123
Musi[a]	1	25°04	25°40	353

[a]Not sown because of drought.
[b]na = not applicable.

A plot trial on the effects of added microelements was carried out in the 1981 dry season, but no significant effects were recorded.

The rainfall patterns were similar on all sites except Sunnyside: a drought with occasional light showers from mid-December to the end of February. Siratro was sown in replicated 1 m wide strips with differential phosphate fertilizer applications. All sowings failed because of dry conditions after sowing.

Stylosanthes

One introduction of Stylosanthes scabra sown in 1977 at Sebele made vigorous growth and is well established, but other introductions of the species on adjacent sites all failed. Both S. scabra and S. hamata should be productive under local conditions but both have proved to be extremely difficult to establish. Seedlings of both species were planted at Sunnyside, Morale, Dukwe, Nata, Motopi, and Sebele. Establishment at all sites except Masama and Nata was good; the plants have fruited but productivity has been low and winter greenness poor.

A collection of types was obtained from CSIRO, Australia, and a smaller one from the Grasslands Research Station, Zimbabwe. These collections were sown at Morale but only one, S. scabra cv. Fitzroy, appears to be promising because of its winter greenness.

Leucaena leucocephala

Details of introductory work on Leucaena are given in previous reports (APRU 1979, 1980). It was concluded from this initial work that it is possible to establish Leucaena under low rainfall, with a minimum of cultivation and a modicum of supplementary irrigation at planting. The program has continued and objectives now are to record the yields of established plots, to extend the geographical range of small-scale plantings, to establish a second large (16 ha) Leucaena browse paddock at Morale, and to investigate the incorporation of Leucaena into communal farming systems.

Dry matter yields of the established observation plots at Sebele and Mahalapye were recorded together with the results from previous harvests. The established plot at Moshu (Ngamiland, Maun region) was not harvested, but it continued to thrive and it is being maintained as a seed bank.

ASSESSMENT OF INVESTIGATION NEEDS — 1979/80

Several events took place at this time that moved investigational work in the direction of the far more complex problems of the communal areas. It had been stated by the pasture research officer at APRU in 1977 that the findings of past work had not been adopted by commercial or subsistence agriculturalists. In fact, a few commercial ranchers were growing some Cenchrus for hay, and there was the odd individual who grew large areas of Lablab not just for the hay but as a green crop before maize. The few dairy farms either relied upon irrigated lucerne, or grew fodder crops for ensiling. But, in total, the assumption was right.

By January 1979, the team members of the evaluation unit of the consultants contracted through the Ministry of Agriculture to monitor and evaluate developments emanating from the TGLP (White Paper No. 2 of 1975) were all in post. A year later they called a seminar to review local knowledge and opinions, and discuss desirable avenues of inquiry, as well as summarize the major problems.

The IFPP had adjusted to the need to concentrate more upon the disorganized but real aspects of subsistence farming, which was "mixed." It had also acquired from the Tribal Land Board 5 ha of communal land for demonstration purposes.

Also in 1979 the preliminary work of the Arable Lands Development Working Group was completed and policy began to take shape. Guided by another consultancy the need to include fodder and pasture work was accepted.

The culmination of these events led to close liaison between APRU and IFPP, and the 1979-80 season saw a series of trial plots put down in the communal area. Species were entirely from available stocks within the country, but 0.5 ha of a maize nurse crop was drilled for undersowing on 20 November and after cultivation 25 different species were undersown at the end of January to coincide with the timing of majority weeding passes by local farmers. Early planted replicated plots of a number of grasses and legumes had been sown on 30 November. This early sowing of the main annual legumes being considered has set the baseline for all further considerations.

Rainfall was favourable, growth throughout was good, and high yields were obtained from the expected species -- Lablab and Velvet bean. The latter set seed earlier than Lablab. Growth and productivity from Phasey bean and Dolichos leichardt was disappointing at 25°S. Stylos failed to establish. Seca and Verana were resown without success. Pot seedlings of Seca, transplanted, survived unproductively until the first frosts. All plots were 5 x 5 m, replicated, with basal 250 kg/ha of single supers.

Siratro germinated well and covered the soil quickly. It has been subjected to alternate plot treatments of cutting at various stages of growth for 4 years, continues to seed, and is vigorous in proliferation. Glycine at Pelotshetlha survives but cannot compete. Cenchrus established well as did Teff in open plots. Establishment from undersown plots were Lablab, Leichardt, Siratro, Cenchrus, Columbus grass, Glycine, and Teff.

A much more ambitious program in 1980-81 was designed with the collaboration of APRU and the Animal Production, Ranch Extension Division of the Ministry. A wide range of species was tested at alternate planting dates, two dates of undersowing under both maize and sorghum, with three fertilizer treatments, and a range of harvesting regimens for the tested fodder species. Winter-hardy forage species were planted through a range of planting dates to assess productive/survivability without irrigation. The ultimate objective was to determine a range of differential fodders capable of becoming established and contributing at different yet critical times during the long dry season. An attempt was also made to determine the feasibility of establishing reseeded strips through the natural veld, using the quickest, simplest, and cheapest methodology.

Three sites in the grazing areas were broadcast with Siratro at 6 kg/ha onto 2 m wide disked strips; 250 kg/ha S. Supers were broadcast at the same time. The seed was mixed with 100 kg/ha LAN and bush harrowed in. Results were similar to APRU findings on ranches: unless the cattle were excluded they used the strips as tracks and destroyed emerging seedlings.

Late sowing in mid February is too late for establishment, and the degree of cultivation needs to be adjusted to soil type. But there is no doubt that Siratro can be established, and both on ranches and at IFPP, good, consistent yields have been obtained from plots and strips under controlled conditions. This investigational program will continue. Two fenced farmer plots were successfully established with Siratro, and this has persisted in spite of intensive grazing-off by goats in the dry season.

The 1980-81 program proved that both grasses and legumes can be established by undersowing of grain crops, that P at least appears to be desirable, and February sowing is less effective. The perennial legumes Siratro and Glycine benefited from the canopy effect, and both Velvet bean and Lablab purpureus as annual "intercrops" can produce good growth from January sowings and continue to vine later than open sites due to canopy protection, provided soil moisture is adequate. Protection from frost, however, is dependent upon stands of the nurse crop.

In 1981-82, the successful establishment of grasses and legumes under both sorghum and maize was repeated, but only one sowing date was used (4 February) due to lack of rainfall in late January. Part of the sorghum block was used to undersow with a range of fodder species as a test of "reinforcing" the stand for increase of biomass. This followed the very successful growth shown by the replicated plots of Columbus grass through all the subblocks of both nurse crops in the previous year. Seven different fodder species were used and mixed in subplots with four different legumes, the annuals L. purpureus and Leichardt, and the perennials Siratro and Glycine. Half of the block was cut and stooked in the last week of April and half left standing. This procedure was a repeat of the previous year and had the dual purpose of observing effect on undersown species as well as comparing yield of stover and changes in crude protein and DDM. Stooking investigations had been undertaken by APRU in 1979 at a number of sites, including IFPP, and had confirmed work elsewhere that there are significant losses in yield and quality in the standing crop from the last week of April.

These average traditional crop residue yields are important as baseline references. They have been used to compare the biomass benefits from fodders grown specifically as livestock feed in the investigational program. The average increase from reinforcing between row sowing of a fodder is 1,100 kg. Average yields are as follows: for fodders planted in January, 3,600 kg and in February, 2,600 kg; annual legumes Lablab and Velvet bean, 5,000 kg; perennial legume Siratro, 4,400 kg; and perennial grass Cenchrus, 3,800 kg.

Reinforcing fodder plots with a legume: replicated plots of eight varieties of fodders were sown at two planting dates in the 1981-82 season. Subplots were cross broadcast with Siratro, *L. purpureus*, and *D. leichardt*. Establishment and growth were variable with the Leichardt and insignificant for late plantings (February) of Lablab, but in all cases Siratro made a useful contribution to quality. Average increase in crude protein analysis of fodder hay is 2.2%. For open plot replications, the range of species tested and established are given in the appendix.

Farmer Participation

There is no background of conscious effort to conserve fodder either from crop residues or standing foggage for personal individual use. Fencing of individual lands under ALDEP assistance and the ongoing investigations of fodder crops have, therefore, presented a new concept to stock owners. The successful production levels at the demonstration plot in the two seasons 1979-81 produced response from local farmers, however, particularly with the harvested legume Lablab. Seven farmer plots of 20 x 20 m planted between 12 and 20 December 1981 with *L. purpureus* enjoyed good establishment and rainfall was satisfactory for growth. Two sites were oversown with a Cenchrus-Siratro mixture in late January, and three others were sown with the same mixture on adjacent plots. All Lablab plots were pulled and dried on tripods, and the farmers allowed to use the hay as they wished. The Siratro plots were grazed by goats.

The interproject meetings had established interest in fodder evaluation, and the Evaluation of Farming Systems and Agricultural Inputs Project (EFSAIP), working in a land area north of Gaborone, recruited five participating farmers in their program to plant an area of Lablab, and separate plots of millet and trudan. The project supervised planting of trial plots of Dr Saunders cowpeas and an area of Cenchrus/Siratro. Yields of fodder were obtained at four sites, but Lablab failed as did the cowpea due to infestation, except at one site.

The exercise was repeated with millet and Lablab with 11 farmers in 1982-83. At the same time, a 4 ha plot was established for demonstration in cooperation with APRU. IFPP recruited 30 volunteers and all areas were planted to a mixture of millet/Lablab on 0.25 ha plots, with some farmers offering a larger area having a second planting of a mixed fodder seeding Columbus grass and forage sorghum in January. The season developed into an early cut-off because of the rains and general crop failure. Seventeen of the farmers had useful yields of Lablab and fodder, however, and they harvested before cattle came into the lands early onto the failed grain crops. The intent to cart home the fodder was encouraging, and again all farmers were allowed to feed it as they wished. Two farmers plowed additional plots to broadcast in 1982-83.

To encourage the concept of feeding, baled hay was used from APRU Morale to supplement the baled fodder from IFPP plots, 12 farmers were recruited, and simple pole racks built in kraals in the dry season of 1982. Eight farmers were asked to feed their work oxen and four were allowed to feed lactating and heavily pregnant cows. This group was provided with the better-quality legume hay from the demonstration plots. The Morale hay was musty and the ox feeding was not a success.

APRU combined with EFSAIP in the winter of 1983 to use the 11 farmers to provide their own stover. This was supplemented with baled stover purchased by APRU. Six animals per farm were fed, three oxen, three cows. This exercise was monitored by APRU.

In the 1983-84 season, 60 farmers at IFPP volunteered to participate. The 17 who had crops to feed the previous year were expected to plow their own plots. All new volunteers had the first 0.5 ha disked and broadcast, but the season was such that most of the work took place over the Christmas period. Second plots were planted in some cases on rains in the second week of January. Rainfall then failed. The few early planted plots began to die back in February, and farmers were encouraged to harvest what they could. A gentle rain from 21 to 23 March (44 mm) germinated some January plantings and more farmers were able to make hay in April. All grain crops had died or never been planted. The season highlighted both the versatility and the difficulties of trying to manage fodder crops in open lands. Cattle were in very early in the arable lands, and a number of additional farmers were encouraged to cut failed and withered sorghum crops.

It is impossible at this stage to know whether the general drought stress encouraged this willingness to get out and cut and haul home some fodder, or whether the concept of providing feed at the kraal is beginning to be accepted. The coming season will see a spread of fodder options put to the farmers with much more farmer-managed planting being required. It is intended to pursue earlier reseeding of range strips, and more farmers will be encouraged to build simple feed racks inside their kraals, including railed areas for the sheep and goats.

In summarizing the results of the first three seasons of investigational work on the demonstration plots at Pelotsetlha, it is important to relate results not only to the wide range of planting dates, methods of sowing, seeding rates, mixes of grasses, fodders and legumes, as well as the alternate procedures of cutting and harvesting times, but also to the most critical of all the variables - the rainfall.

In observation trials conducted over 5 years, clearly the critical months of January and February allowed a variety of planting times, and in particular the late undersowing of a nurse crop, to be successful in the first 3 years. The argument that it would have been better to have had the frustrations of the past two seasons initially, is not accepted. Had that occurred, there is no doubt that the consensus would have been that there were very few options open to investigation. Fortuitously, circumstances have enabled a very wide range of possibilities to be examined, and best and worst expectations compared with the alternatives of quantitative and quality needs.

The period under review has seen a very real awareness develop with regard to the magnitude of the problem confronting the silent majority of the people, the small herdowners living and surviving in a communal environment that no longer provides a semblance of symbiotic equilibrium. Two successive years of drought have accelerated this awareness, but it is not yet possible to assess whether the old familiar attitude of complacency will return if good early rains bring the rangelands back to life again.

What is absolutely certain is the fact that large numbers of cattle have died, and, unfortunately, a high percentage of those will have been the breeding females always under the most stress. Even more distressing is the inevitability that it will be the small herds that will have suffered most. The ownership of cattle is very skewed. Forty-five percent of all rural farmers own less than 10 head, and they only planted 20% of the land under cultivation, and they harvest the least (1983 Agricultural Statistics). They are truly the most disadvantaged. Statistics also show that the ratio of calves to cows is lower than the average, and females almost certainly have to be put into the yoke.

It will be argued with some truth that this large section of the community is the least able to make any proper use of the arable land for fodder and that the fodder concept is designed to assist the above-average section of the rural households. However, this is not really relevant. All share the communal grazing. This also includes the large sections of improperly utilized arable land that never comes under the plow in any given year. The area planted in 1983 was 305,000 ha, which is only 12% of the suitable arable area.

There is great potential for better use of the large interspatial areas in the land areas, and all could benefit. The provision of better-quality grazing is equally important as a measure to combat the carrying capacity and the nutritional deficiencies of the herds. Here small herds have the advantage because their needs are more easily met.

The principal need, however, is for the unit rural community to group together and tackle the problem collectively and responsibly. The Ministry of Agriculture is currently seeking ways to give assistance to such responsible leadership. Collectively, a grazing community must be helped to improve and stabilize its own natural resource. This whole pasture and fodder program is just one component of the scene.

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APPENDIX

Species planted at IFPP 1981-84 for evaluation and investigation

Fodders

Trudan, Fodderbank, Supergrazer, Haygrazer, Columbus grass, Sweet Sudan grass, Babala millet, Sordan. Australian importations: Millet Feedmill II, Forage sorghums: Jumbo, Sugargrazer, Speedfeed

Grasses

Cenchrus ciliaris, Molopo, Gayndah, USA-W. Australian, Panicum coloratum, Bambatsi, Sabi panic, Panicum maximum, Green, Gatton, Digitaria, Smutsii, Erianthe (Rhodes grass), Anthephora pubescens, Phalaris tuberosa, Kentucky Blue Fescue, Setaria, Nandi, Paspalum, plicatulum, notatum, Eragrostis, Teff, Curvula, Ermelo, American leafy

Legumes

Dolichos, Lablab, Leichardt, Siratro, Phasey bean, Glycine, Tinaroo, Lucerne, Barrel medic, Jemalomg, Vetch, Crown, Wooly pod, Sainfoin, Trifolium, repens, Stylosanthes, Hamata, Scabra, Humilis, Guyanensis, Cook, Schofield, Endeavour, Cowpea, colonna, Velvet bean, Pigeonpea

Winter Forage

Rye, polko, koolgrazer, Hybrids, Agroticum, Triticale (4), Radish, Japanese fodder, satinajina, nooitedacht

REVIEW OF THE USE OF IMPROVED PASTURE SPECIES IN MOZAMBIQUE

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Abstract *Mozambique, with an area of 779,500 km^2, encompasses a wide range of ecological conditions. It has a summer rainfall regime of 350 mm to 2,000 mm/year. The southern quarter of the country contains 80% of the total cattle population, much of it in the communal sector. State enterprises account for most of the rest.*

Little research has been carried out into the use of improved pastures or pasture species, and most of our knowledge comes from successes or failures of their use on state farms.

Elephant grass is widely used as fresh fodder or for silage, and other large grasses also. Of the legumes leucaena and siratro show promise, as does Lablab purpureus *to a lesser extent.*

In the future it is hoped to utilize existing research station and state farm facilities in various ecological zones to observe management requirements and performance of selected pasture and fodder species. Emphasis will be placed on green and preserved fodders, and on seed production. Dual-purpose species that can also be used as food for humans will be looked at for use in the communal sector.

A major constraint will be the lack of technical agricultural personnel and practical managerial training will be a priority.

Mozambique covers an area of 779,500 km^2 from 11° to 27° S latitude and ranges in altitude from 1,600 m to sea level. Mean annual rainfall ranges from 350 mm near the South Africa-Zimbabwe-Mozambique border to 2,000 mm in the highlands of Zambezia Province. Consequently, the range of ecological zones is great, necessitating a flexible approach to pasture research.

There are three broad zones in Mozambique as regards cattle production -- south, central, and north. The south, consisting of the Provinces of Maputo, Gaza, and Inhambane, contains 80% of the national herd of 1.3 x 10^6 head. The zone is trypanosomiasis-free with the exception of small areas due to Glossina austeni, and this is probably the major reason why the vast majority of communally owned cattle are found here. The vegetation is mostly savanna, and much of the natural pasture is what is termed mixed veld and sweet veld consisting of Themeda triandra, Panicum maximum, and Urchloa mosambicensis along with Digitaria and Eragrostis species. Due to the reasonable summer rainfall (600-800 mm), the occasional dry-season rains, and virtually frost-free conditions in much of the zone coupled with fairly extensive areas of reasonably fertile soils, the potential for utilization of improved pasture species in beef and milk production is quite high. There is also good potential for irrigation along the major rivers.

The central zone is extremely varied and includes the alluvial plains of the Zambezi valley, the dry areas of Tete Province, the high rainfall forest areas of parts of Zambezia and Manica Provinces, and the extensive coastal plains of the Sofala and Zambezia. Some of this zone is covered with Miombo woodland. In most of the area, trypanosomiasis is important. Here, most cattle are found on larger enterprises, particularly in coconut plantations or on sugar farms. Angonia, on the border with Malawi, is exceptional in that it contains many cattle in the communal sector. In general, much of the area can be termed mixed veld, with sour veld in the higher areas and sweetveld in the drier areas of Tete. In this zone, there is also much potential for irrigation.

The northern zone, the Provinces of Niassa, Cabo Delgado, and Nampula, consist mostly of Miombo woodlands on poorer soils with a high incidence of trypanosomiasis. The few cattle found in this zone are predominantly in the state or private sectors, not in the communal sector. There is also little tradition here of cattle raising. Although rainfall is good, there is a long dry season and the grass is coarse and of poor quality for much of the year. Potential for irrigation is low.

USE OF IMPROVED PASTURE AND PASTURE SPECIES

Much of the pasture research that has been done in Mozambique concerns reconnaissance-detail surveys of botanical composition of natural pastures (Myre 1960, 1971, 1972; Lousa 1973) and was carried out in colonial times. More recently, research has been done into control of bush encroachment on natural rangelands (Sweet 1980), but there has been little research on improved pastures. Most of our knowledge has come from successes and failures in the use of these pastures on State Farms (Servoz 1982). Some research has been carried out at Mazeminhama (Myre 1969), and Namaacha and Umbeluzi in the south of Maputo Province on good basalt-derived soils, but has limited applicability to much of the rest of the country. In addition, some small trials are being carried out in Angonia near the Malawi border into suitability of various species for smallholder production (Centro Rural de Desenvolvimento 1984).

Some of the species tried in Mozambique are shown in Table 1 with indications as to their uses and success. In general:

Leuceana leucocephala has proved successful in many areas and is fed green to animals or grazed periodically in situ. Both plantations and row planting in natural pasture have been tried, using direct sowing or raising first in tubes in a nursery. Sufficient seed is collected for the country's present requirements. Mimosine poisoning has not been reported, but cattle have not been fed for long periods.

Siratro (Macroptilium atropurpureum) has been successfully grown and used under a wide range of

Table 1. Improved legumes and grasses used in Mozambique.

Species	Use/management	Success	Zone
Legumes:			
Cajanus cajan	. Fodder and edible seed production	. Good in many areas as a human food crop; tall and open, so some weed problems	South
Centrosema pubescens	. Pasture under coconuts		
Desmodium uncinatum			
cv. greenleaf			
cv. silverleaf	. With elephant grass for fodder or silage		
	. Grown under irrigation with *Cynodon plectostachyus* for dairy fodder	. Used successfully	Manica
Lablab purpureus local cvs	. Fodder and edible seed production	. Good growth; low management requirements. Good seed and leaf production. Not yet tried under grazing	Maputo
Neonotonia wightii	. With elephant grass for fodder and silage	. Good results	South
cv. Cooper	. Reinforcing natural pastures	. Reasonable results, but not persistent under grazing	South
cv. Tinaroo	. Reinforcing natural pastures	. Some success; better in cool season	South
Leucaena leucocephala	. Reinforcing natural pastures; planted in rows	. Much success; recommended	South
	. improving fertility of old cotton fields		North
	. Block planting for fodder; sometimes under irrigation	. Grows well under dryland conditions	Whole country
	. Smallholder production for fodder	. Successful; much potential	Central, south
Macroptilium atropurpureum	. Reinforcing natural pastures	. Some success; tolerant of fire and drought, but expensive	South

	• With elephant grass for fodder or silage	• Very successful; recommended; used for milk cattle and pigs	South, central
	• Improving fertility of old cotton fields		North
Medicago sativa	• Under irrigation for dairy fodder	• Very demanding in management and soil requirements; not recommended	South
Pueraria phaseolioides	• Pasture under coconuts		Zambezia
	• Fodder	• Some success at higher altitudes; can be planted from stolons	central
Mucuna	• With sorghum and maize for silage under dryland conditions	• Grows well	South
Stylosanthes guianensis cv. fine stem oxley	• With Cynodon plectostachys under irrigation for dairy fodder		Manica
	• Reinforcing natural pastures	• Successful; probably best species for this but does better if cut rather than grazed	South
cv. Cook	• Reinforcing natural pastures		
Stylosanthes hamata cv. Verano	• Reinforcing natural pastures		
Stylosanthes humilis cv. Townsville	• Reinforcing natural pastures		
Stylosanthes scabra cv. Seca			
Grasses:			
Cenchrus ciliaris cv. Molopo	• Reinforcement of natural pastures mixed with Siratro Stylo cv. Cook, Stylo cv. Verano, Leucaena	• Successful establishment but did not persist; better in drier areas	South
Chloris gayana	• Reinforcement of natural pastures with Siratro	• Good results	

(continued)

Table 1. Concluded.

Species	Use/management	Success	Zone
Cynodon plectostachyus	. Under irrigation or good rainfall, with heavy fertilization for dairy fodder	. Good results	Manica
Melinis minutiflora			
Panicum maximum cvs	. Reinforcement of natural pastures mixed with Siratro, Glycine cv. Cooper, Leucaena		South
	. Fodder or silage for beef and dairy cattle	. Good results, but stand needs replacing after 3 years; recommended	South
Pennisetum americanus cv. Babala	. For grazing or silage	. Good preliminary results; dual purpose crop as seed production good	South
Pennisetum clandestinum	. Hay making	. Good at higher altitudes but needs irrigation; production not high	Central, south
	. Lawn grass and soil stabilizer	. Widespread and good results	Whole country
Pennisetum polystachyon	. Fodder or silage for dairy herd	. Good preliminary results; drought and flood tolerant	South
Pennisetum purpureum	. Fodder for dairy and beef herds and pigs, with or without irrigation	. Very good results; widely used; recommended; best grass for dairy feeding, but needs irrigation	Whole country
	. For silage alone or with Siratro, Desmodium, Glycine	. Good results	Whole country
Setaria sphacelata			
Setaria splendida	. Fodder for dairy herds	. Good production and palatable but needs plenty of water	
Sorghum spp.	. Grown for silage under dryland conditions; sometimes with Stilozobium	. Successful; widely grown as food crop also	South

Sources: Personal communication from various state farm managers and Tilak Viegas et al (1981); Tilak Viegas and Servoz (1981); Servoz (1982).

climatic conditions and is generally recommended for dairy production and reinforcement of natural pastures. It is also used green for pig feed. Although top growth was killed in many areas during the recent drought, siratro regrew well after the following rains.

Lablab purpureus local cvs. have shown much promise in the south. Management and fertilizer requirements are low and seed production is good. An added advantage is that the seeds can also be used for human consumption.

Elephant grass (Pennisetum purpureum) is widely grown, often under irrigation, as green feed or silage for dairy cattle and sometimes for pigs. But due to insufficient fertilizer and erratic irrigation, productivity is often low. Mixes with siratro and Glycine cv. Cooper have shown promise.

Cynodon plectostachyus has been used with success on some dairy farms under irrigation and with heavy application of fertilizer. Elsewhere it has been grown for hay. Good results have also been obtained under dryland conditions but under good rainfall.

Lucerne (Medicago sativa) was grown some years ago under irrigation to provide lucerne-meal to feed factories in the Limpopo valley. More recently, attempts to grow it in the south on alluvial soils under irrigation have been rather unsuccessful due to too large an area being cultivated and insufficient management. It is too demanding in its requirements.

On some State Farms normal or fodder sorghums (Sorghum alum, S. sudanese, S. vulgare) are grown to make silage, and on occasion maize (Zea mays) also. Sorghum growth with Stilozobium under dryland conditions has produced significant quantities of fodder for dairy herds.

Both methods of improving pastures -- cultivation of stands of improved species and oversowing of natural pastures -- have been tried. Oversowing or reinforcement of natural pastures (Themeda - P. maximum) has been done with Cenchrus ciliaris, siratro, Neonotonia wightii cv. Cooper, Stylosanthes guianensis cvs. Oxley and Cook, and Leucaena, but most have not persisted, probably due to insufficient management. The rows of Leucaena have proved quite persistent, however. Establishment in many cases has been by using tractor-drawn disc harrows. It is hoped in the future to utilize animal traction more in the communal sector.

Although attempts have been made for Mozambique to become self-sufficient in seed, in particular for siratro, there is a great shortage (with the exception of Leuceana) in the country. The recent drought severely affected a pilot program of small-scale trials on many state farms in the south of the country (10) and seed collection was not possible. A few private dairy farmers are using improved pasture species, but in general all private and communal sector livestock are raised on natural pastures.

The Instituto Nacional de Investigações Agronómica has recently set up a small Rhizobium culture facility. Most of the present production is for soybean inoculant, but there are facilities to grow various other strains of rhizobia on an experimental scale. It is hoped to expand these facilities in the future.

FUTURE RESEARCH PRIORITIES AND STRATEGIES

As so little pasture research has been carried out in Mozambique, we have no appropriate or successful research methodologies yet. At present, the emphasis is not on research as such but on utilization of established or reasonably successful species or practices.

However, the most promising and appropriate lines of inquiry for us would be the following: small-scale farm trials of promising new species and varieties in various ecological zones; to determine optimum methods, in the various zones, of establishment, fertilizer requirements, and management of siratro, Leucaena, elephant grass, and others under higher management levels on larger farms, both state and private; the same as above but for the lower management levels and low-risk requirements of the smallholder in the communal sector, for both milk production and selective dry-season feeding of animals; appropriate techniques for reinforcement of natural pastures with legumes such as Leucaena, Stylosanthes, Siratro, and Neotonia, for either dairy ranching or beef production; appropriate fodder species, alone or in combination, for silage production; and appropriate grass/legume combinations for fodder production under irrigation.

A fruitful line of inquiry, which should also be more readily adopted by communal sector farmers, is the use of dual-purpose crops. These, for example *L. purpureus*, *Cajanus cajan*, sorghum, and millet, can be utilized for human food and the residues (or failed crop) used for animal fodder in the dry season.

It is hoped to initiate these investigations on various existing research stations covering the major ecological zones of the country, or on various state farms with the capacity to implement them. Research should also concentrate on economic aspects of pasture improvement. In addition emphasis will be placed on commercial seed production of selected species. A problem in the implementation of this program of investigations will undoubtedly be the shortage of technical agricultural personnel that can be allocated to it.

Much research work on improved pastures and fodder species has been carried out, particularly in Zimbabwe and Australia, that is appropriate for our conditions. The results of this research should be applied on a trial basis in Mozambique in our various ecological zones before being implemented on a production level.

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PASTURES IN LESOTHO

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Abstract *Work in Lesotho on tested pasture species and commercially used pasture species has been limited in the past. A general lack of plant breeders and researchers has been a major factor in the delay in forage advancements. The expensive, long-term investments that are needed in such work has been another key factor. However, the main reason for lack of emphasis on pasture development is the extreme overgrazing problem that still exists. As long as the ranges are 200 and 300% overstocked, dependent on location, improvement seedings will simply aggravate the overgrazing problem. Nevertheless, research information upon the adaptability of various species will be valuable when the appropriate numbers of livestock are maintained on these lands.*

Pasture research and plant improvement in Lesotho has not been progressing as rapidly as forage scientists anticipated. Smith and Rhind (1984) attribute this situation to several causes. The long-term programs that are necessary to ensure systematic plant improvement is a prime reason for a lack of development. The lack of a substantial number of complementing researchers in plant improvement programs is another important factor for moderate growth in the field. Thus, workers in the field have had to rely upon results in allied fields and other countries to bring about changes in pasture productivity.

By formal definition, Winburne (1984) identified pasture as "a fenced or unfenced tract of land on which farm animals feed by grazing." Under this definition, rangelands of Lesotho fit within the scope of any discussions of pastures.

Rangelands, on the other hand, are historically defined as "those areas of the world, which by reason of physical limitations, low and erratic precipitation, rough topography, poor drainage or cold temperatures, are unsuitable to cultivation and which are a source of forage for free-ranging native and domestic animals as well as a source of wood products, water, and wildlife" (Stoddart et al. 1975). Tiedeman and Motsamai (1981) defined rangelands of Lesotho as "land not suitable for cultivation because climate is either too cold, too wet or too dry, the soil has too many rocks or the slope of the land is too steep." Essentially, the two definitions are the same except that values other than domestic animal products are not emphasized in the latter definition. Few, large-bodied wildlife now exist on the mountainous rangelands of Lesotho.

On an average, rangelands of the world cover 47% of the earth. However, in Lesotho, rangelands cover approximately 70% of the land surface. Not only does Lesotho have a higher percentage of rangelands than most countries but the majority of these are mountainous. In contrast to other mountain rangelands, almost all of this mountain terrain is devoid of native forest trees (Motsamai 1984).

A Bureau of Statistics (1984) report indicated that there were 562,372 cattle grazing in the country. An additional 1,337,448 sheep and 930,414 goats also grazed the lands of Lesotho in addition to horses. Motsamai (1984) remarks "with the present numbers, there are 1 animal unit (au)/3 ha and yet available forage can only permit 1 au/8 ha."

Research information on the adaptability of various plant species and varieties within species is essential in restoring and improving the capacity of the grazing lands and animals in Lesotho. When proper numbers of livestock are attained on these pasture and rangelands, then such information will be of utmost importance in achieving these goals.

EXOTIC FORAGE SPECIES

In Lesotho, limited pasture research work has centred on establishment and, to some extent, productivity of forage species. Previous work was seldom recorded. As a result, research programs lacked continuity from one expatriate scientist to the next. Thus, work was done in isolated projects. Major efforts were initiated in the centre of mountain ranges near Thaba-Tseka. Studies were conducted under Canadian International Development Agency (CIDA) funding from 1975 to 1981.

The rangelands' carrying capacity in Lesotho has declined due to nonscientific management over many years going as far back as 1933 when the worst recorded drought hit the country. Emphasis was placed on overseeding adaptability programs that were selected to emphasize improvement of the rangelands and, therefore, increase the carrying capacity. Few farmers are able to produce sufficient food from the crops that they grow. This group accounts for approximately 85% of Lesotho's population. Thus, the time is not right to go into full-scale research on fodder crops because farmers will continue to concentrate on producing food for themselves. Through communal grazing, every livestock farmer is entitled to and has access to grazing land, so improvements will benefit a greater portion of the population. Modifications of the communal grazing system include introduction of a permit system, which has already been introduced in the country, and other systems that include consideration of charging a grazing fee, part of which will be used to improve range resources and thereby increase the carrying capacity.

Overseeding Trials

The objectives of the initial studies at Thaba-Tseka were to introduce forage species that would establish rapidly and improve total production. Other factors of interest included palatability and high nutritive value to the grazing animal (Beckman 1981).

From 1975 to 1979 trials were conducted on approximately 172 ha of rangeland.

Overseeding trials have been tried during every month of the year except the winter period. Most of the seeding work was done from September through November. The best time to overseed was from mid-December to mid-February. During this period, rains are frequent, temperatures of both air and soil are optimum, and there were usually no major winds to blow seed or cause high evaporation rates. If seeding were carried out later than February, the newly established seedlings have no chance of surviving the fairly harsh winter conditions at high altitudes. Most of the overseeding was done at 2,000-2,700 m above sea level.

Overseeding trials were conducted on each aspect (north, east, south, and west), as well as in intermediate positions. Seeding on the major aspects were tried in November through February. Later, germination and initial establishment were found to be best on the north, northeast, and east-facing slopes.

Legume and Grass Species Trials

With regard to the adaptability of various varieties of grasses and legumes, individual species and mixtures were investigated (Table 1).

Results of the mixture trials indicated that initial germination was good, and establishment of some of the introduced species was very good. The overseeding trials, which were carried out by Beckman (1981), came to the conclusion that: (a) _L. perenne_ (Ariki ryegrass, Ruanui ryegrass) and _T. repens_ (Huia white clover) responded best under different range conditions; (b) Ryegrasses established faster than the clovers, but that the clovers persisted longer in the sward; (c) _D. glomerata_ (cocksfoot), _T. pratense_ (timothy), _L. perenne_ (manawa, Italian ryegrass), and _P. tuberosa_ (harding grass) did not do well; (d) mid-December and mid-February were the optimum times for overseeding; (e) north-facing slopes gave the best response, when overseeded. Much of the seed received in Lesotho in the past was of poor quality and was offset by overseeding -- up to 50-55 kg/ha for grass mixtures and 35-40 kg/ha for a grass-legume mixture. The recommended

Table 1. A list of varietal mixtures of grasses and legumes introduced at Thaba-Tseka.

Species (mixtures)	Common name or cultivars
1. Lolium perenne	Ariki Ruanui Tama westerwolds
2. Lolium perenne	Ariki Tama westerwolds
Dactylis glomerata	Apanui
3. Lolium perenne	Tama westerwolds Ruanui
Trifolium repens	New Zealand white clover Huia
Trifolium pratense	New Zealand late red clover
Phleum pratensis	Kahu
4. Lolium perenne	Ruanui Tama westerwolds Ariki Manawa
Dactylis glomerata	Apanui
5. Lolium perenne	Ruanui Tama westerwolds Manawa
Dactylis glomerata	Apanui
6. Lolium perenne	Manawa Tama westerwolds
Phalaris tuberosa	Harding grass
Dactylis glomerata	Apanui
7. Pennisetum clandestinum	Kikuyu
8. Lolium perenne	Tama westerwolds Ruanui
Dactylis glomerata	Apanui
Trifolium repens	New Zealand white clover Huia (continued)

Table 1. Concluded.

	Trifolium pratense	Late red clover (n.2)
9.	*Lolium perenne*	Manawa
	Bromus inermis	Smooth brome
	Trifolium repens	Huia
10.	*Lolium perenne*	Ruanui
		Tama westerwolds
		Ariki
	Dactylis glomerata	Apanui
	Trifolium repens	Huia
11.	*Lolium perenne*	Ruanui
	Dactylis glomerata	Apanui
	Phleum pratensis	Kahu
	Trifolium repens	Huia
	Trifolium pratense	Late red clover
12.	*Lolium perenne*	Ariki
		Ruanui
	Trifolium repens	Huia
13.	*Lolium perenne*	Ruanui
		Manawa
	Dactylis glomerata	Apanui
14.	*Lolium perenne*	Ariki
	Trifolium repens	Ladino white clover
15.	*Lolium perenne*	Tama westerwolds
	Trifolium pratense	Giant red clover
16.	*Trifolium repens*	Ladino clover
	Phalaris tuberosa	Harding grass
17.	*Dactylis glomerata*	Cocksfoot
	Bromis inermis	Smooth brome
	Trifolium pratense	Giant red clover
	Trifolium repens	Ladino white clover
18.	*Eragrostis curvula*	Weeping love grass
	Trifolium repens	Ladino white clover
19.	*Festuca arundinacea*	K-31 tall fescue
	Trifolium pratense	Giant red clover

legumes made up 20% of the mixture; and (f) cost of overseeding was expensive, however, because of high seeding rates.

Beckman (1981) felt that the trials were generally unsuccessful because animal trespassing did not give a chance for permanent establishment of the forage species. At least some indications have been given on the suitability of various introduced species.

NATIVE PASTURE AND RANGE SPECIES IN LESOTHO

For native species, efforts have been concentrated on those species that would respond well to various cultural practices after establishment. The overall objective was to examine species that would not only have potential for pasture and range improvement but produce adequate seed quantity and quality.

The native Eragrostis curvula is a strong and productive pioneer perennial. Although of relatively low palatability, this grass is an important species in Lesotho at the present stage of forage production. The ability to resist grazing and control erosion in mountainous terrain are valuable assets of this widely distributed species and are good reasons for further investigation.

The E. curvula cultivators of "ermolo" and "American leafy" have both proven to be adapted for forage production in the lowlands, foothills, and mountainous areas of Lesotho. Forage production varied considerably. A study in the foothils of Lesotho indicated no significant difference between forage yields between the two cultivars.

In further studies, ermolo responded to fertilizer application in the same manner as has been found in other Southern African countries. However, with the interrelationship of clipping, it was found that increasing the period between clippings increased forage production response from fertilizer only up to the 10th week of clipping intervals. Forage production values continued to be good, ranging from 1,500 to 9,000 kg (dry matter)/ha dependent upon fertilizer-application rate and clipping interval.

FUTURE ADAPTABILITY TRIALS IN LESOTHO

A revised list of potential plant species for Lesotho pasture or range seeding has been prepared. This list is adapted from that of Tiedeman (1981), a former ecologist on the Farming Systems Research, Range Division of the Ministry of Agriculture. The revised list does not include species names that have not proven to be successful in various sites. The list also includes several new cultivars such as Agropyron spicatum Secar, which has recently been developed from dryland rangeland conditions. Although only Agropyron riparian has been introduced into Lesotho its adaptive success indicates that this genus may provide alternate potential species for successful seeding in the mountainous rangelands of Lesotho.

Revised List of Plant Species that may have Potential for Lesotho Pasture or Range Seeding

- Grasses for reestablishing damaged rangeland for cool summer rainfall areas of 15-23 inches/year (native pastures are usually as productive as seeded pastures in this zone) (Meredith 1955); Cynodon dactylon, Themeda triandra, Eragrostis lehmanniana, Digitaria pentzii, D. smutsii, Cenchrus ciliaris, Sporobolus fimbriatus, Chloris gayana, Urochloa mosambicensis, and Tetrachne dregei.

- Plant species for seeding cool, summer rainfall areas of 23-30 inches/year (native pastures are usually as productive as seeded pastures in this zone also) (Meredith 1975):

(a) Dryland - Chloris gayana, Panicum maximum, P. coloratum, P. coloratum var. makarikariensis, Digitaria pentzil, D. swazilandenisis, D. smutsii, Cynodon plectostachyus, Cenchrus ciliaris, and Agropyron spicatum - secar.

(b) Wetlands - Echinochloa pyramidalis, E. holubii, Pennisetum purpureum, Hemarthria altissima, Paspalumdilatatum, P. urvillei, and Agropyron riparian.

(c) Hay - Eragrostis curvula, E. plana, Cynodon dactylon, and Chloris gayana.

. Species for summer rainfall areas of 30-40 inches/year (cool summers) (Meredith 1975):

(a) Summer and fall grazing areas: Grasses Pennisetum clandestinum, Paspalum dilatatum, P. urvillei, P. notatum, Acroceras macrum, Hermarthria altissima, and Eragrostis curvula. Legumes - Trifolium pratense (Montgomery red, kenland red, and cow grass varieties) and Trifolium subterraneum.

(b) Winter soil moisture areas - Lolium multiflorum, L. perenne, Bromus catharticus, Dactylis glomerata, Festuca elatior, Holcus lanatus, Phalaris tuberosa, Agropyron elongatum - Largo.

(c) Hay fields: Perennials - Paspalum dilatatum, P. urvillei, and Pennisetum clandestinum. Annuals - Panicum laevifolium, Setaria pallide-fusca, Digitaria horizontalis, and D. sanguinalis.

. Grasses for erosion control: Wet meadows (very wet) - Phragmites communis, Typha latifolia, and Leersia hexandra.

(a) Meadows (moist) - Imperata cylindrica, Paspalum dilatatum, P. urvillei, Hemarthria altissima, Setaria sphacelata (this type of tuft grass permits water erosion on sloping land between tufts), Pennisetum clandestinum (may spread into adjoining arable land, difficult to eradicate).

(b) Dryland - Cynodon dactylon, Digitaria abyssinica, and D. scalarum, (all three may spread into adjoining land and are difficult to eradicate); D. swazilandensis; Panicum repens; Hyparrhenia hirta; and H. aucta.

(c) Contour banks - Pennisetum purpureum, Setaria sphacelata (var. 1185 and 1193), Paspalum urvillei, P. dilatatum, Hyparrhenia hirta, Chloris gayana, and Eragrostis curvula.

(d) Waterways - Paspalum dilatatum, P. notatum, Chloris gayana, Digitaria swazilandensis, Hyparrhenia hirta, Eragrostis curvula.

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PASTURE RESEARCH AND DEVELOPMENT IN ZAMBIA

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Abstract *Past and present pasture research and development in Zambia is reviewed. The review includes objectives of the present program where attention is drawn to the importance of a pasture seed production research program, evaluation of pasture crops, improvement of* dambo *sward, and use of research information by livestock owners. Future research priorities and strategies are also presented.*

Zambia lies between latitudes 8° and 18°S and stretches from longtitude 22° to about 34°E, covering an area of 756,000 km^2 with an altitude from 900 m to 1,300 m above sea level. Rainfall is highest in the North (1,000-1,400 mm) and lowest in the South (700 mm). The rainfall is seasonal and falls between November and March. Temperatures are moderate with a mean minimum temperature in June-July of 6 °C in the South and 11 °C in the West with a mean maximum in October of 34 °C in the South and 30 °C in the North.

It has long been known that poor nutrition, disease, and inadequate water are major biological impediments to attempts at increasing livestock production. So far, upgrading of animal potential and proper veterinary care have been the major emphases of the Ministry of Agriculture and Water Development in Zambia. It is only since the beginning of the 80s that provision was made (pasture seed production research program, cattle development projects, etc.) to improve nutrition, which is the most important problem affecting livestock in Zambia.

There is no question that the cheapest and most economical way of feeding livestock is through improved pastures. Experimental results indicate that improved pastures will enhance the production of more meat, milk, butter, and cheese, which are the staple foods that affect the nutritional status of any nation.

Today, with the high cost of livestock feeds and good prices for livestock products, much more attention is being paid by some commercial farmers in Zambia to pasture production, but, generally, pasture crops are still not very well known in Zambia. Farmers must become more aware of pasture crops and their management techniques before widespread acceptance and use becomes common.

PASTURES IN ZAMBIA

Trapnell and Stent present reviews of pasture research in the early 1930s. Stent (1933) first demonstrated the rapid seasonal fall in the herbage quality of Hyparrhenia veld, as measured by crude protein and crude fibre levels, and showed that repeated cutting maintained better-quality herbage. Trapnell (1932, 1933) and Trapnell and Clothier (1957) differentiated the grassland types of the Southern and Central Provinces and discussed the effects of management practices and particularly grazing pressure on grass succession. They suggested that mowing, rotational grazing, and the seeding of veld should be investigated. The total yield of uninterrupted growth of veld was about 5 t dry matter (DM)/ha. Growth after April was negligible.

Pasture research work stopped after this period because of the depression and retrenchment. Research began again in the 1950s. During the next 30 years in Zambia to the present significant contributions have been made, notably by Smith (1959, 1961a,b, 1962, 1963a, 1964a,b), Brockington (1960, 1961a,b, 1962), Jones (1963), van Rensburg (1965, 1967a,b, 1968, 1969a,b), Astle (1965, 1966), Verboom (1966, 1972), Verboom and Brunt (1970), Rees (1974), Paterson (1975), Thorp (1978), Heery (1979), and others as described in publications and annual reports. Smith (1959, 1961a,b, 1963a,b, 1964a,b), Brockington (1960, 1961a), and Jones (1963) have studied individual veld species, milk production, fertilizer response, and stocking-rates on veld that had a relatively small effect on weight gain in the rainy season but had a significant linear effect and a lesser quadratic effect on weight loss in the dry season. Fertilizer responses of veld were: yield and percentage of crude protein increased linearly with the application of sulphate of ammonia in the range of 450-900 kg/ha. Where 200 kg N/ha was applied as sulphate of ammonia DM yield was tripled compared with unfertilized Hyparrhenia grassland (from 2 to more than 6 t/ha). The residual effect of fertilizer application was slight. After 3 years of application, only the high levels of N had a residual effect in the 4th year, and this was exhausted by the first residual harvest. In the early 1950s (Smith 1962), pasture and fodder species were introduced from other African countries and Australia, e.g., Panicum coloratum, Cenchrus ciliaris, Eragrostis curvula, etc.

The highest yields of dry matter and crude protein were achieved by the two cvs. P. coloratum, and Cynodon nlemfuensis and C. aethiopicus. The lowest yields were achieved by Cynodon dactylon, Setaria sphacelata, and to a lesser extent Chloris gayana. Smith (1963a) succeeded in introducing legumes into the veld. Stylo and glycine were oversown into burnt veld after the soil in the plots had been turned slightly by hand to simulate a light cultivation. Both legumes nodulated effectively without inoculation. Stylo doubled the yield of herbage dry matter and increased the yield of crude protein, compared with veld alone. Van Rensburg (1969a) has described a list of 15 grasses with brief notes on their performance. There appeared to be a limited supply of the good grasses of C. ciliaris, Panicum maximum and P. coloratum.

Several legumes were tested and selected among which the most promising species were: Siratro, imported from Australia in 1962/63; Stylo; Glycine; and Centrosema. Mixtures of the first three legumes with Rhodes grass doubled the dry matter and crude protein yields compared with pure Rhodes grass. Van Rensburg (1969b) also started a plant breeding section for grasses and legumes; 44 selections of Rhodes grass were tested for simulated grazing and for cutting at the hay and later stages. The best selection was 147B, yielding

10 t/ha when cut monthly and 15 t DM/ha when cut at the hay stage and again after the hay stage.

Astle (1965, 1966), Verboom (1966, 1972), Verboom and Brunt (1970), Rees (1974), and Heery (1979) were concerned with what may be described as an ecological survey of the sand veld areas in the southern and western provinces and the vegetative ecology of seasonally flooded areas commonly known as "dambo" (i.e., mbuga or vlei) grassland in the southern province, related particularly to fodder resources. These flood plains are very important for dry-season grazing. The survey indicated that the present land use system is extensive and wasteful in terms of the use of land resources. The species composition of dambo grassland around Choma was described. In these dambos, Loudetia simplex grassland occupied about six times more area than did Leersia hexandra. The wet season productivity of these dambos was a little higher in the L. hexandra grassland sites than in L. simplex. Some of the planted pastures species of (Panicum repens and Acroceras macrum) in dambos were also under observation. Under favourable conditions, A. macrum - Nile grass gave better basal cover, and better herbage quality, better growth after August, and probably better wet-season productivity than P. repens - Torpedo grass under the same conditions. Under poorer conditions, Torpedo grass appeared to do better. Studies on exposed flood plain sward in the vicinity of Mongu, Western Province (Kulich 1973, 1976, 1977) showed that the natural sward is relatively rich in plant species.

On the flood plain (where approximately 75% of the cattle graze well from about June to December) the effect of the use of fertilizer, irrigation, and cutting frequency on production and chemical composition of silage and hay and botanical composition were studied. The main results of 5 years of investigation are as follows:

(a) Fertilizer: Significant response to nitrogen has been recorded (up to 500 kg N/ha) and phosphorus (up to 100 kg P/ha). Potassium gives no response. Boron and sulphur tend to increase yields but not significantly.

(b) Irrigation: Five different frequencies to different percentages of water field capacity (WFC) - 60% and fool WFC. When irrigation started in the middle of August it gave the highest yields for two cuts. When irrigation started later (mid and late October) a good yield was received for one cut, but this was only possible because of very late rains, which permitted a late cut in January. Irrigation block with 80% WFC gave highest DM yield.

(c) Silage and hay: Yields were 8 t/ha DM (30 t/ha of silage and 9 t/ha of hay) at 400 kg N/ha with 14% CP.

(d) Influence of cutting frequency: There was a strong linear response up to the highest fertilizer level under three cuttings (October, November, and January).

(e) The typical vegetation that exists during the rainy and flood season includes _Vossia cuspidata_, _Echinochloa stagnina_, _E. pyramidalis_, _Oryza barthii_, and a small percentage (3-5%) of legumes -- _Sesbania_ spp. and _Aeschynomene fluitans_. _A. macrum_, _P. repens_, _Paspalum_ spp. and _Setaria_ spp. become dominant under irrigation and fertilization regimes in the cool dry period.

Browse

The dry season in Zambia extends from March/April to November. From June or July onward, when the woodland grasses that have been well grazed become parched, the bush species start to produce the new seasons' flush of leaves. These have a very high crude protein content. Lawton (1968) suggested that if woodland is being stumped for grazing, those species utilized as browse by cattle should be retained as coppice. Throughout Zambia, various forms of an agricultural system called Chitemene, a type of shifting cultivation, has evolved. In the Northern Province at Misamfu Region Research Station, Kasama, Zambia (Hood 1972), where this study was carried out, the Chitemene system involves clearing an area of miombo woodland about 10 times the size of the required cultivatable garden area. Cutting is by lopping and the branches are then carried to the area of the future garden and stacked to make a circular bed of fuel about 0.7 m deep. The stacks are kindled and a thick seed-bed of ash is left that enriches the soil with minerals including nitrogen and phosphorus. The garden will be used for 4-5 years and then abandoned. Chitemene is a familiar system to subsistence farmers, so it was decided to incorporate certain aspects of this traditional agricultural practice in the plans of the management of the miombo woodland. After the trees have been lopped, following the custom of the Chitemene system, the regrowth, high in crude protein, grows to a height available to cattle as browse. In August, the browse eaten contained 12.5% CP, in comparison to 2% CP content in grasses at that time. At this time it is apparent that the available browse could make a significant contribution to both protein and energy requirements of grazing cattle.

Legumes

Recommendations and conclusions from the research studies conducted by Potter (1972), Paterson (1975), Prins (1975), and Craufurd (1978) can be summarized in the following. It is recommended that a high seed rate be used for undersowing; for example, 3 kg/ha for the wetter regions, up to 5 kg/ha for the medium rainfall regions, and up to 8 kg/ha for the low rainfall areas.

Research conducted in the 1970s was directed toward the establishment and management of legumes and grasses/legumes including the local legume Rhynchosia sublobata because of its early growth toward the end of the dry season and its fire resistance.

A series of establishment trials with legumes in Southern Province (Paterson 1975) showed that the best stands of Stylo and Siratro were produced by a sequence of disc, broadcast seed, and fertilizer, rolled with a Cambridge (ring) roller. This was superior to drilling with a Nisbett drill, hand planting in Kraal manure, or other practices that omitted either discing or rolling. When undersowing grass/legumes in maize, maize was planted in mid-November using normal land preparation and fertilizer practices including N top dressing. Immediately after the last weeding, the pasture legumes (siratro, Silverleaf desmodium, Glycine, and Archer) were drilled at a rate of 2-4 kg/ha into alternate rows of the maize. Star grass runners of Rhodes grass seed were planted in the remaining vacant rows about 2 weeks later. In subsequent seasons, only 200 kg/ha/year of single superphosphate was applied to the grass/legume mixtures. Experiments showed that without using weed killers the best results with undersowing pasture legumes in maize were obtained by sowing the pasture species as early as possible.

Maize intercropping with legumes in 2-year experiments showed promising results in areas with sufficient rainfall for both crops. Two methods of intercropping were used. One is to establish legumes in rows at the same width as for maize, harvest legume seed in the dry season to recover the costs of establishment before planting maize in the 2nd year. With minimum tillage, interrow areas were cultivated to prepare a seedbed for maize and to control weeds. The maize was then sowed and, during the growing season, the weeds were controlled. After the maize harvest, the cattle were grazed on the dry maize stover and the green legume during the dry season. Maize sowing was repeated in the same manner in the following rains. With good management, this system could work satisfactorily for many years.

The second method is to establish legume stands by drilling or broadcasting, harvest the legume seeds in the dry season to recover the cost of establishment, plough and harrow in the 2nd year at the start of rains, control the weeds with a selective herbicide like Preforan or Lasso, give the legume an opportunity to reestablish from old plants or seeds (left over from the previous season), graze the maize/legume mixture after the maize grain harvest for a short period, and let legumes flower and set seed. With the next rains plough and repeat the procedures.

Legumes for fodder conservation should be cut around early March, when peak production is reached. Because of the differences in growth rhythm, fire and frost resistance, and drought tolerance, it is recommended that a mixture of two to three legumes be sown. Rest periods of 12-16 weeks are recommended between grazings for high, dry-matter production.

Grasses

To obtain a complete cover of Star grass within one season, the planting of splits at 0.5 x 0.5 cm is recommended. Adequate soil fertility is required for good establishment.

The conservation of fodder as hay or silage is recommended as the best system for dry-season feeding, although veld supplement with 10% urea molasses gives additional weight gains during the dry season. In general, grasses have been shown to be capable of producing large quantities of fodder when adequately fertilized with N and P (from 8 to 15 t DM/ha).

Even the best grasses fail to provide protein sufficient for maintenance of stock during the second half of the dry season, although fodder conservation can partially overcome this problem. In the pasture breeding program, the selection of Rhodes grass and Star grass and the legumes glycine, Siratro, and Stylo was started by Craufurd (1978) in the early 70s. However, the seed stocks of Rhodes grass have been very mixed and must undergo further selection. The four Star grass selections (selections 4, 5, 6, and 24) were established in multiplication plots for distribution. Craufurd's experiments showed that seed production at Mount Makulu, was not very satisfactory as seed yields varied greatly from year to year depending upon the degree of coldness in May, June, and July.

Irrigation Pastures

The irrigated pastures and fodder crops research project set up by Thorp in 1978 at the National Irrigation Research Station (Mazabuka) was developed to study management and productivity of imported and local pasture grasses and legumes and fodder crops under irrigation. In the case of lucerne, the current commercial cultivar, Hairy Peruvian (strain Gilboa) appears well adapted to irrigated conditions in the Central and Southern Provinces. Normal yields range from 1.5-3 t DM/ha/cut during the dry season. The recommended sowing period is from March to June, at seed rates of 15-25 kg/ha. The cultivar Hairy Peruvian may be harvested as frequently as 10 or more times per year at the early flowering stage. Such frequent harvesting is likely to reduce weeds and clear disease build up.

In the first-year lucerne requires large amounts of phosphorus, 80 kg/ha. No requirement for potasium was shown, but annual applications should be made (60 kg/ha for the 1st year) to replace that removed through frequent harvesting. No response to sulphur was found on a sandy clay loam soil but annual application of 20 kg/ha should be made, particularly on sandy soils. For subsequent years lucerne requires levels of 40 kg P, 30 kg K, 4 kg Bo, and 20 kg S/ha. Weeds are a major problem for lucerne in Zambia. Preliminary results indicate that the best herbicide available in Zambia for 1st year is 75% Dacthal applied at preemergence at 6-8 kg/ha. Artificial inoculation of seed with an appropriate rhizobial strain is strongly recommended.

For Star grass, selection five appears to be the most promising selection in terms of dry matter yield. Yields in excess of 20 t DM/ha/year are obtainable. Star grass responds well to irrigation and N fertilization during the hot, dry period from September to November but does not respond well during the cool, dry period from May to August. This is mainly because of low night temperatures. None of the tropical legumes tested gave yields comparable to lucerne during the cool season. Of the legumes evaluated Leucaena leucocephala, Desmodium intortum, D. uncinatum, Neonotonia wightii, and Lablab purpureus showed some responses to irrigation during the warm season.

Two temperature perennial grasses showed some promise and may merit further evaluation. These are Festuca arundinacea and Phalaris tuberosa. Oats (Avena sativa) yielded well under irrigation during the dry season. For Star grass-legume mixtures, the most promising combinations were Star-lucern and Star-silverleaf desmodium under irrigation during the period from September to November and the subsequent rainy season. Fertility conditions, particularly nitrogen, were low. Other promising grass-legume mixtures under irrigation and with low fertility in Zambia were C. ciliaris and P. coloratum cv. Bushmen Mine with Medicago sativa, N. wightii, or D. uncinatum.

Between 1978 and beginning of the 1980s, pasture research work in Zambia was almost at a standstill. However, with the reorganization of the Research Branch into a number of teams with a multidisciplinary approach, the Animal Husbandry and Pasture Research Team was established and this has stimulated some activities.

CURRENT WORK

The main objectives are to carry out and conduct research work necessary to achieve the goals described in the Third National Development Plan (TNDP) and future development programs. The main activities of the Pasture Research Section (consisting of two Pasture Research Officers, one Chief Agricultural Supervisor, one Senior Agricultural Assistant, and two Agricultural Assistants) are:

(a) To provide research for the development and management of improved pasture and for better utilization and conservation of native pasture.

(b) To provide a consultancy service for the pasture seed growers as well as others involved in pasture improvement.

(c) To produce and maintain pasture seeds and avoid the shortage of suitable seed, of both grasses and legumes.

(d) To find stable legume-grass systems, and to develop improved low-input pasture technology to increase livestock production.

(e) To investigate the improvement of dambo pasture. Large areas of dambo soils, e.g., usually cover about 30% of agricultural land in the Southern Province. Using dambo more effectively may offset the dry season limitations of cattle production and improve production of natural veld (valuation of pasture crops and dambo research).

The need for cultivated species has long been recognized in Zambia but the availability and cost of pasture seed has been a serious constraint to production. To offset this, a joint GRZ/SIDA Pasture Seed Research Production Programme has been set up and a high research priority has been given to the production of pasture seed in Zambia. The following species have been identified: legumes - Macroptilium atropurpureum, D. uncinatum, Macrotyloma axillare, N. wightii, Stylosanthes guianensis, M. sativa, Crotalaria juncea, Mucuna pruriens, L. leucocephala, and grasses - Chloris gayana, C. ciliaris, P. maximum, C. nlemfuensis, Pennisetum purpureum, A. macrum and P. repens.

The results to date demonstrate the potential that there is for local production of different kinds of pasture seeds if a good management and good permanent maintenance breeding program is introduced (Kulich 1981, 1982, 1983). Considerable advance has been made for example with siratro where the annual seed yield ranged from 220 kg to 500 kg/ha. Yields of other species included Neonotonia which yielded from 200 kg to 400 kg/ha, lucerne cv. hairy Peruvian from 300 kg to 400 kg/ha, Lablab No. 16 from 4 to 6 t, and cv. Somerset from 2 to 4 t/ha, respectively. Sunn hemp was from 1 to 1.5 t/ha, Silverleaf desmodium from 70 kg to 90 kg/ha, and Rhodes grass cv. Boma produced very good seed yields in establishment year (500 kg/ha). Peak seed yields for the other two Rhodes grass cultivars, Katombora and Mbarara, were observed in the first year at 150 kg to 400 kg/ha, respectively, and Green panic yielded 200 kg/ha, etc. The amount of rainfall, timing of precipation, problems with irrigation machinery, the age of pasture crops, and other interactions appeared to be the factors determining variation of seed yield from year to year.

In the program of evaluating the suitability of various pasture legumes/grasses/mixtures, 14 pasture legumes, 9 grasses, and 23 grass-legume mixtures were used in the current study. Preliminary results showed that 14 treatments are very promising, e.g., pasture legumes DM yield 5-10 t/ha, grasses 4-7 t/ha, and grass-legume mixtures 4-8 t/ha.

Improvement trials of dambo pasture-14 are being carried out in areas in the Southern Province planted pasture (Nile grass and Torpedo grass) under different management regimes. The planted species significantly out yielded the natural dambo sward and Torpedo grass was more productive on the DM yield than Nile grass. The total DM herbage increased with N fertilizer: in the natural dambo sward yields increased from 3 to 7 t/ha; Nile grass yields increased from 4 to 8.5 t/ha, and Torpedo grass production was raised from 4 to 10.5 t/ha DM.

Application of Scientific Information by Livestock Owners

The success of any research in agricultural development depends upon the practical application of its results by the intended users. In Zambia, it is possible to see from visits that some of these changes in technology do exist on livestock farms, although it is difficult to quantify these changes because little is documented.

There are three types of livestock farmers in Zambia. These can broadly be classified as: (a) commercial, (b) subcommercial, and (c) subsistence or traditional farmers. Commercial farmers tend to use more research information than do the emergent and traditional farmers. For example, in pasture production, more and more commercial farmers around Lusaka, Chisamba, Muzabuka, and Choma are beginning to grow more grass/legume mixtures to counteract the economic effects of high-priced fertilizers. Emergent and traditional cattle owners are, to some extent, utilizing research information through adoption of cultural methods they learn from the extension officers.

To reinforce the speedy use of research results in this sector, some recent technological scientific findings are being applied at cattle development-area centres scattered throughout the country.

FUTURE RESEARCH PRIORITY AREAS AND STRATEGIES

National and Regional Strategies

In view of the fact that intensive forage production using expensive machinery/technology and fuel is not an economic proposition for most farmers in Zambia the goal of our continuing research activities should be "to develop low-cost pasture technology and also take into consideration the soil fertility."

A certain amount of basic knowledge has been acquired, but continued investigation into the following aspects is needed: collection, selection, and evaluation of germ plasm adapted to climate, soils, diseases, and pests; best and most economical methods for establishment legumes in existing pasture; development of cheap seed production technologies; develop forage-production technology under irrigation; and development of complementary cattle-production systems and the development of complementary animal health and management practices.

With these investigations, it is also important that some emphasis be given to extension work in pastures. The preparation of farmer-oriented literature, and the training of extensionists in aspects of pasture production are facets of the program which must now receive more attention.

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PAST AND CURRENT TRENDS OF PASTURE RESEARCH IN KENYA

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Abstract *This paper looks at the trends of pasture research in Kenya over a span of some 80 years. A review of the agriculture production systems is given to enable the reader to appreciate the historical background of the earlier impetus of research, which was geared toward meeting the needs of the large-scale, mixed-farming enterprises. The change of farm sizes and land ownership, postindepedence in 1963, brought about a reappraisal of the research and extension policy.*

Research endeavours of the early 20s-70s produced tangible benefits to the needs of the era. The main thrust was on ley grasses as practiced under the mixed-farming system used during that period. Legume pastures and fodder were researched. The results were extended to the farmers through personal visits, field trips, agricultural shows, and through technical bulletins and local farmers' publications.

Pasture research from the early 70s tended to continue on the lines of ley grasses and accumulation of germ plasm; the late 70s to the early 80s have seen a greater emphasis being paid to more relevant research on the needs of the smallholders in the high potential areas and in the marginal agrarian areas. A greater awareness of the role of arid pastoral areas in maintaining animal productivity led to accelerated research in those disciplines by both the Kenya government and through internationally aided research projects.

Scarcity of land and a severe competition with crops in the high potential areas due to high opportunity costs of crop production has led research to be concentrated on intensive fodder production, utilization of farm by-products, and on development of other feed resources.

It is concluded that the challenge to research and extension in Kenya is to meet demands for milk and meat production, both increasing at about 5.3%/year.

This paper gives an outline of past and current impetus in pasture research activities as dictated by the prevailing agricultural production systems, then and now. Published results appearing in scientific journals, theses, booklets, advisory leaflets, or as reports and working papers should be available from the various pasture research stations given in Appendix 1.

The total land mass of Kenya is 569,260 km^2. The land falls into six ecoclimatic zones; zone 1-6, as given by Griffiths (1962). Kenya has distinct wet and dry seasons with almost the whole country experiencing a bimodal distribution. Peak rains occur around April and November. About 72% of the land mass receives less than 500 mm annual rainfall, 13% receives from 500 to 750 mm, 12% receives from 750 to 1,250 mm, and about 4.3% receives more than 1,250 mm rainfall (Potter 1983).

Seasonal variation in temperatures is slight, but the highlands tend to be cooler. The mean air temperature at the coast is about 27 °C and the general rate of decrease with altitude is approximately 5.3 °C/1,000 m. A diurnal variation of 10 °C is typical, except at the coast where it is less and at elevations above 2,000 m where it is likely to be greater (Pratt and Gwynne 1978).

AGRICULTURAL PRODUCTION SYSTEMS

Pasture research in Kenya has tended to be influenced by the prevailing agricultural production systems. It is relevant, therefore, to give a fair coverage of the production systems prevailing before independence in 1963 and the changed pattern of the post independence era.

More than 80% of the Kenya land mass, or 46 x 10^6 ha, is unsuitable for arable farming and intensive livestock production because there is too little rain or no access to sufficient water. Table 1 shows agricultural enterprises practiced in the six ecoclimatic zones.

Comprehensive reviews on Kenya's agricultural sector; agriculture development policy; African land tenure reform; and the development of the small farm areas, the large farms, and the range land areas are given by Senga, Smith, Okoth-Ogendo, Heyer and Waweru, Hinga and Heyer, and by Kaufmann, respectively, in a book edited by Heyer et al. (1976).

From the 1890s to the 1950s agricultural development policy in Kenya was almost entirely European settler oriented although scant attention was paid to African agriculture from the 1930s to the mid 1950s. At that time, before independence, it was possible to make a clear distinction between large- and small-scale farming in terms of land tenure and size; large-scale farming was non-African owned and the small-scale farming was African owned. The African farms were in the so-called nonscheduled areas whereas the large-scale non-African owned farms were designated "scheduled" areas. By 1960, the "scheduled" areas comprised about 3.0 x 10^6 ha of which 1.4 x 10^6 were in mixed farming areas and the remaining 1.6 x 10^6 ha were in plantations and ranching areas (Senga 1976).

As noted earlier from the mid 1950s some attention was given to developing African agriculture but it was not until the commissioning of the famous "Swynnerton Plan" in 1953 that a real intensification of African agriculture was considered seriously. The plan also outlined different strategies for different areas depending upon rainfall, population densities, and other climatic and production features.

This trend again gained momentum, on the eve of independence in 1961, when a "Million Acre Settlement Scheme" was started for purchasing 1.2 x 10^6 acres of largely mixed farming land from the former "scheduled" areas for distribution to Africans (Senga 1976). Post-independence, many other settlement schemes were undertaken by the Kenya government in collaboration with the British government. The change in land owner-

Table 1. Agricultural enterprises practiced in the six ecoclimatic zones of Kenya (adapted from Senga (1976)).

Zone	Area	Agricultural enterprises
1	800 km^2 - 1% of the land mass	High altitude above tree line. Mostly barren except for moorland or grassland here and there. Land use - water catchment and tourism.
2	53,000 km^2 - 9% of the land mass comprises bulk of Kenya's high potential agriculture area	Embraces the bulk of Kenya's forests, both indigenous and planned. Agricultural potential very high especially in the highlands. Coffee, tea, and pyrethrum are important cash crops. Cotton yields well at lower elevations. Intensive smallholders grow pulses, potatoes, some maize, vegetables, and a very high proportion of smallholder dairy production, poultry and some pigs at higher elevations.
3	53,000 km^2 - 9% of the land mass. Medium potential agricultural land	Most of the large-scale mixed farming areas growing hybrid maize, wheat, and barley. Small-scale holders grow maize, cotton, groundnuts, pulses, and oilseeds. At lower elevations at the coast cashew and coconuts are also grown. Livestock does well on both large farms and on smallholdings.
4	53,000 km^2 - 9% of the land mass. Marginal agricultural	Most of the earlier-established ranches are in this zone. Subsistence crop farming and livestock keep-

(continued)

Table 1. Concluded.

Zone	Area	Agricultural enterprises
	potential	ing are the important occupations of the smallholder. Most of Kenya's game is found in this zone. Pastoralists occupy an important position.
5	300,000 km^2 - 52% of the land mass	Wildlife is important in many areas. Moderate rangeland development potential. The zone has been the focus of much of the present and proposed livestock development programs. Pastoralists occupy an important position.
6	112,000 km^2 - 20% of the land mass. Most of Northern Kenya - sparse and erratic rainfall. Annual grasses spring up after the rains	Predominantly pastoralist country. Limited livestock development exists, but productivity depends on land use as well as on potential, population, infrastructure, access to markets, development resources, etc.

ship also continued through private individuals and cooperatives buying land while a few farms remained within the government parastatals to maintain their size and production enterprises. In most cases, farms bought by cooperatives were subdivided into small units to settle many families.

The picture that has emerged now is that of a very much diversified agricultural production. However, the majority of plantations and ranches remained in the hands of non-Africans because they were costly to buy and run. However, many of the large-scale mixed farms have ended up being divided into smaller units but some few remained as large units and have either changed hands or are with the same owners. The result has been accelerated production in the former "non-scheduled" areas and in the settlement schemes as a result of the nonrestrictive nature in what the African farmer can grow and rear. Shares of small farms as a percentage of the value of gross marketed output increased from 18% in 1954 to 22.2% in 1962 and up to 52.5% in 1972 (Senga 1976). These percentages are exclusive of commodities used on the farm for subsistence.

The major animal production enterprise by the small-scale farmers in the former "scheduled" and "non-scheduled" areas is dairying. By 1970 an estimated 418,000 grade dairy cattle, or 60% of the dairy national herd, was in the hands of the smallholders and only 284,000 head remained on the large-scale farms (Chema 1983). Available statistics indicate that in 1978 out of the 901 x 10^6 L of milk available for consumption smallholders produced 69%, the large-scale farmers produced 17%, and the remaining 14% came from the pastoralists and commercial ranchers. Other minor ruminant livestock enterprises of the smallholders are sheep and goats used for ceremonial purposes and sometimes to provide extra cash income. However, the Ministry of Agriculture, in collaboration with Winrock International has been working on a project to introduce dairy goats to the smallholders in Western Kenya and the Nyanza Districts.

Many of the large-scale unit ranches are still operational and some new ones, especially in the Coast Province, have come up. But the major livestock enterprises, in terms of cattle, sheep, and goats, are still in the hands of the pastoralists. Some cattle, sheep, and goats are also kept by the agrarian communities in the more marginal areas.

PASTURE RESEARCH UP TO THE 1970s

Until the recent past, Kenya relied on grass ley production in the high potential areas to raise dairy cattle, sheep, and high-quality beef. Leys played an important role in the mixed-farming systems. A few large farms were using improved pastures to raise dairy cattle, sheep, and beef. As noted earlier, the role of the smallholder in these enterprises was almost nil. Naturally, therefore, pasture research was mainly geared to cater for the "needs of the day." The major thrust of pasture research was, therefore, on ley farming, legumes, and fodders.

In 1908, the first Government Experimental Farm was set up at Kabete to provide information and training for prospective European settlers. Among the activities was the evaluation of pasture species. Activities expanded when in 1922 the Scott Agricultural Laboratories (currently called National Agricultural Laboratories) were established. The first Pasture Specialist, called a Grassland Improvement Officer, was appointed in 1930. Planted grass, legumes, and fodders were evaluated at Kabete and at demonstration farms at Njoro, Molo, Kitale, and Rongai to cover the main ley farming areas, while grazing studies of the indigenous swards at Kabete, Naivasha, Ngong, and Machakos were laid down to cover the main ranching areas (Ministry of Agriculture 1980).

An attempt was made in 1935 to look into pastoral areas. Grazing blocks were established in Maasai to monitor vegetation, but the study was abandoned due to difficulties of controlling grazing patterns caused by lack of water supply points and traditional land tenure patterns.

A review of all grassland research activities was held in 1950 and it was decided to establish regional centres to serve the main ecological zones. Ol Joro Orok, which had been established 6 years earlier, Molo and Kitale were established as centres for the higher and wetter regions, whereas Katumani and Marigat were established for the drier medium-altitude areas. That was also the beginning of a research program to provide information suitable for the smallholder African farmer as it was becoming clear that the possibilities of famine might cause a drain on the central administration. Programs from the main stations were coordinated with the established substations such as at Embu, Kisii, Kakamega, and also on demonstration farms so that the full range of situations could be investigated. To increase geographical coverage, pasture research activities were extended to Coast Province in 1960.

From the early 1950s, an East African based program of agricultural and veterinary research at Muguga included an Animal Production Division, and among its activities was the determination of the nutritive value of various feedstuffs, pastures included.

The achievements of the thrust of pasture research, gauged by the requirements of the times, were quite substantial. Good ley grasses were produced from the local varieties based on the level of success of dry matter production, vigour, nutritive quality, and persistency. Seeding activities and resistance to diseases were also looked into. Among the notable species of ley grasses were the Chloris gayana and its cultivars and Setaria sphacelata (Setaria ancepts). In the higher altitude areas it was common to see exotic ley grasses such as fescues and perennial rye grasses with or without legumes. A number of other grass and legume species and their ecotypes were collected and described botanically. They were evaluated to assess their suitability for the different climatic zones.

For all the promising and cultivated grasses, fodders, and legumes cultural practices such as seed bed preparation, time of planting, spacing, and seed rate were established. Weed control, fertilizer application, time of harvesting/grazing, and cutting heights and frequency were also studied. Forage conservation methods as hay, standing hay, or silage were studied and established (Orodho 1983). The picture that emerged within the high-altitude, high-potential areas between the 50s and 60s was that of a highly complex mixed farming system using very productive ley and legumes pastures and some other fodder crops. The excellence of farming in those areas was comparable to any in the world.

Through extension, the research results were passed to the settler community and it was easy for it to be propagated through pamphlets produced at the research stations and distributed on field days and at show grounds; as well as through field visits to the farms. Printed literature reached the farmers through the papers "The Kenya Farmer," the "Royal Agricultural Society journal," and the "Kenya Weekly News." Scientific papers have been published in various international journals (Appendix 2).

PASTURE RESEARCH FROM THE 1970s TO THE PRESENT

With the changes in land ownership and farm size, the earlier objectives of pasture research were slightly modified to direct attention to the small-scale farmers in heavily populated areas. However, in some of the major research stations, some work was still mainly based on areas that had no bearing on the requirements of the smallholders. Some major criticism on these lines were voiced by the Ad hoc Committee set up to review maize and pasture research in Kenya (Ministry of Agriculture 1980).

The establishment of the Range Management Division within the Ministry of Agriculture signaled the determination of the Kenya government to develop the range areas. The drier areas program, which had been based at Marigat and Katumani research stations, was separated from its parent station at Kitale. Work on drier areas continued to be carried out at Katumani and on a newly established Kiboko Range Research Station in 1967.

The Kitale-based programs, inclusive of those carried out on its affiliated out stations, were strengthened by a number of technical-assistance projects. In 1966, the Dutch-aided grass-breeding project was established with a major emphasis on ley grass production. From 1971-77 the British government funded a research projected based at Kitale. The terms of reference of this project as spelt out by Goldson (1977) were:

(a) To provide scientific assistance that would enable the accumulated knowledge on pasture and forage species to be measured in terms of animal production and to be integrated into farming systems.

(b) To provide assistance for the extension of the results of pasture and forage work from the Kitale and Molo environments to other ecological areas important for intensive livestock production.

A detailed report of the activities of the program is given in the report mentioned and a list of technical reports that were compiled is also given.

In 1974, the Food and Agriculture Organization of the United Nations (FAO) Norad-assisted project for grass collection and evaluation was initiated to provide a nationwide evaluation of plant species of potential usefulness for increased animal production. Work on this project was carried out in all the research stations given in Appendix 1 to cover the wide ecological zones of Kenya. In 1980, a United Nations Development Programme (UNDP)/FAO project on forage development and seed multiplication was started. Its terms of reference have been to develop some of the promising forage materials identified by the previous projects by producing seed or vegetative materials and by carrying out preextension trials on selected farmers' fields.

Apart from the reorganization at Kitale station, which has resulted in more relevant and wider objectives as spelt out by Orodho (1983), other pasture research stations have placed more emphasis on research based on zonal needs. Embu Agricultural Research Station has redirected its emphasis on the production of high-yielding fodder crops with appropriate technology to cater to the needs of the smallholder who produces milk under zero and semizero grazing.

From about the mid 1960s to the end of the 1970s the Kenya Agricultural Research Institute (KARI), formerly the East African Agricultural and Forestry Research Organization, concentrated in research on increasing beef production in the semi-arid areas. Currently, a limited program on range research has been maintained and the emphasis has recently changed to research oriented toward smallholder dairy production using Bana grass, deep litter from poultry, and other smallholder feed resources such as the role of systematic maize defoliation. Over the next few months there are plans to produce technical bulletins on their work to be used by farmers and extension workers.

Most of the research on rangelands is carried out at Kiboko Range Research Station. Katumani Research Station concentrates on research relevant to smallholder farming conditions prevailing in the Katumani and its environs. The current objectives of Katumani Research Station as spelt out by Orodho (1983) are

(a) To select and improve the nutritious forage and fodder crops that can supplement naturally grazed pastures in part or in whole with particular attention to the needs to sustain animal productivity during the dry season.

(b) To investigate the possible ways of maintaining dry-season fodder reserves such as the use of drought-tolerant fodder trees and shrubs and experimental development of small-scale technologies for preserving fodders.

(c) To maximize production and utilization of methodologies for farm by-products and crop residues.

(d) To increase output per animal through the use of better feeding management.

The Coast Agriculture Research Station, consisting of Mariakani and Mtwapa, cater to the humid coastal belt and the less-wet hinterland, respectively. Research work has an emphasis on identification and testing of pastures suitable in both areas.

The early 1970s saw a productive UNDP/FAO beef research project at Lanet on maize silage. From the mid 1970s to the present, research has changed to forage sorghum as an alternative to maize silage. From about 1979 a Small Ruminant Collaborative Research Support Programme (SR-CRSP) was started with the collaboration of the Kenya government and a consortium of U.S. universities under the leadership of Winrock International. The SR-CRSP in Kenya is on dairy goats. One of its activities is to look into feed resources for small ruminants in smallholder areas and also to study the nutritional and metabolic aspects of these feed resources (Sid Ahmed and Onim, personal communication).

In 1976, an Integrated Project in Arid Lands (IPAL) was started. Among its activities have been the study on fodder biomass, stocking rates, grazing/browsing characteristics of the small stock and camels, and a nutritional profile of the available feeds in the arid and semi-arid study areas.

At Egerton College, some work is being done on stall feeding of dairy cattle. At the Department of

Animal Production, University of Nairobi, a substantial amount of work has been done on digestibilities and utilization of pastures, fodders, and arable farm by-products such as sweet potato vines, wheat and barley straws, and on maize stover. (Those publications preceded by an asterisk in Appendix 2 refer to published work on arable farm by-products.)

Academic staff in the Department of Animal Production are also doing collaborative research with SR-CRSP and some Ministry of Agriculture research stations were at some stage involved in the IPAL programs.

ACHIEVEMENTS AND EXTENSION OF RESULTS

The achievements of almost 80 years of research are reflected in various published works. Orodho (1983) gives a comprehensive list of the publications stemming from the research. But the greatest tangible achievements were the thriving large-scale animal production enterprises of the 40s-60s in the "scheduled" areas. Currently, achievements are noticeable in the smallholder areas within the ecoclimatic zones 2 and 3.

But as late as 1980 concern was voiced on the relevancy of pasture research from the postindependence period. It was noted that emphasis was being made on extensive forage plant collections, which resulted in a large gene bank being established at Kitale. Efforts were first being made on evaluation of the species collected in terms of agronomic practices and animal productivity potential. It was also noted that pasture agronomic research had not been adequately supported by evaluation of animal productivity and that research on developing drought-resistant fodders in marginal areas was wanting. These unhappy observations are beginning to change now, and it is hoped that with increased impetus on smallholder-oriented research in both the high potential and marginal arable areas the situation will improve even more. Together with these changes in research accent there is a need for increased manpower training in the areas of pasture research and extension. Extension of the available relevant research is being undertaken at various levels through tours, field days, demonstrations, public media, seminars, agricultural shows, and publications. The recently introduced "teach and visit" program by the Ministry of Agriculture under the sponsorship of the World Bank has had a positive impact on crops but without parallel achievements in animal production.

The challenges for pasture research and extension is to meet the expected demands for milk and meat production, both increasing at about 5.3/year. Increased milk production from the high-potential areas must come from the smallholders but they are now producing milk from land that is facing a very severe competition with crops owing to the high opportunity costs of the crops enterprise. Increased meat production will continue to be expected to come from the marginal and submarginal areas but there must be a better and safer understanding of the whole range of complex production factors coupled with adequate provision of the necessary infrastructures. These are difficult challenges.

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APPENDIX 1: RESEARCH STATIONS/INSTITUTIONS WORKING ON PASTURES AND RELATED DISCIPLINES

National Agricultural Research Station, P.O. Box 450 Kitale.

Western Agricultural Research Station, P.O. Box 169, Kakamega.

Nyanza Agricultural Research Station, P.O. Box 523, Kisii.

Small Ruminant Collaborative Research Support Programme, P.O. Box 252, Maseno-Kisumu.

Marindas Agricultural Research Station, P.O. MOLO.

Nyandarua Agricultural Research Station, P.O. OL JORO OROK.

National Animal Husbandry Research Station, P.O. Box 25, Naivasha.

Beef Research Station, Private Bag, Nakuru.

Department of Animal Production, University of Nairobi, P.O. Box 29053, Nairobi.

International Livestock Centre for Africa (Kenya), P.O. Box 46847, Nairobi.

Kenya Agricultural Research Institute (Muguga), P.O. Box 30148, Nairobi.

Embu Agricultural Research Station, P.O. Box 27, Embu.

Integrated Project in Arid Lands (IPAL/UNESCO), P.O. MARSABIT.

National Dryland Farming Research Station - Katumani, P.O. Box 340, Machakos.

Kiboko Range Research Station, P.O. Box 12 Makindu.

Bachuma Range Research Station, P.O. Makinon Road.

Animal Husbandry Research Station, P.O. Box 30, Mariakani.

Coast Agricultural Research Station, P.O. Box 16, Kikambala.

APPENDIX 2: SUPPLEMENTARY BIBLIOGRAPHY

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PASTURE RESEARCH IN TANZANIA

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Abstract *Pasture research started in the 1930s in Tanzania. Since then, investigations have continued in various aspects of pasture and range production, management and utilization, and pasture plant species introduction and evaluation. This paper briefly outlines these investigations with a note on the current organization and the main areas of pasture and range research.*

With a total area of 939,701 km^2, Tanzania lies approximately between 1° and 12° South and 29° and 40° East. It is essentially a land of plains, valleys, plateaus, and mountains with the altitude varying from 0 m at sea level to well over 5,900 m on the snow-capped peak of Mount Kilimanjaro.

The climate, which is greatly influenced by altitude, varies from tropical subhumid to semi-arid. According to the ecological classification of Pratt and Gwynne (1977), 74% of the country's land surface receives 1500 mm or less annual rainfall, which is considered to be inadequate for the production of most agricultural crops in the absence of irrigation. Livestock production is, therefore, the main activity in these relatively dry areas. Variability in rainfall also influences the distribution of the human population: areas receiving more than 1,500 mm rainfall are, generally, more densely populated than those receiving 1,500 mm or less rainfall.

In 1978, the country had a human population of 17.5×10^6, of which about 94% lived in rural areas, and a livestock population of 12.1×10^6 cattle, 5.5×10^6 goats, and 3.6×10^6 sheep (Ministry of Agriculture 1979).

PASTURE RESEARCH

In Tanzania, pasture research dates back to the 1930s and was pioneered by such scientists as Staples (1937, 1938, 1945), Staples et al. (1942), French and Van Rensburg (1952, 1956, 1958), among others. Investigations that have been carried out since then have been reviewed (Mehta 1974) and the following account is only an overview of the investigations.

Range Ecology and Vegetation Surveys

Ecological and vegetation studies have been conducted in various parts of the country by many workers including Phillips (1930), Greenway (1933), Scott (1934), Pielou (1952), Walker (1974), and Kahurananga (1979). The results of some of these and other studies formed the basis for the production of various vegetation maps of Tanzania and East Africa as a whole (e.g., Gillman 1949; Heady 1960; Pratt and Gwynne 1977).

Range Management and Utilization

Studies on stocking rates have been carried out in various ecological zones in the country (Staples 1938; Walker and Scott 1968; Broatch 1970; Lugenja and Kajuni 1979). Grazing systems (rotational, continuous, and deferred and their combinations) have been evaluated in the subhumid to semi-arid areas (Staples 1937, 1945; Walker 1968; Walker and Scott 1968). Walker and Scott (1968) concluded that combinations of rotational and deferred grazing gave better results than any of the other systems used singly.

Considerable work has been done on the control of brush and weeds on rangeland using mixed herds of cattle and goats (Hornby and van Rensburg 1948), fire (Staples et al. 1942; van Rensburg 1952, 1958), and by mechanical means (Brzostowski 1960). However, most of the results have not been published in widely circulated journals (for instance, a large amount of data is to be found in the Kongwa Pasture Research Biannual Reports 1962, 1968).

The use of mineral fertilizers on natural pasture has been shown to improve both the yield and the quality of forage in various parts of Tanzania (Evans and Mitchell 1962; Anderson 1965, 1968; Walker 1969b; Hendy 1975), but moisture stress reduces drastically the yield response in low rainfall areas (Lwoga 1981).

Introduction and Evaluation of Pasture Grasses and Legumes

The introduction, evaluation, and selection of pasture grasses and legumes have been undertaken for the humid to subhumid areas (Naveh 1966; Naveh and Anderson 1966; Anderson and Naveh 1967; Hopkinson 1979), subhumid to semi-arid areas (Walker 1969a; van Voorthuizen 1971), and semi-arid areas (Owen and Brzostowski 1967; Wigg 1973). The main evaluation criteria used in these investigations included persistence, dry matter production, resistance to grazing, drought resistance, and quality. Earlier studies evaluated the quality (mainly the chemical composition and in vivo digestibility) of various grass and legume species and their mixtures and browses (French 1939, 1941, 1945, 1950, 1957; van Rensburg 1956). Results of more recent evaluations (e.g., Lane and Lwoga 1978; Mukurasi 1978; Myoya 1980) are yet to be published in a form readily available to readers outside Tanzania. The results of some of these studies have been used for making tentative recommendations on the suitability of grasses and legumes for pasture establishment in the various ecological zones in the country (Table 1).

Pasture Establishment, Management, and Utilization

Rather little information is available on the suitability of different establishment methods for sown pastures, but several workers (Northwood and Macartney 1969; Lane and Lwoga 1978; Rukanda and Lwoga 1981) have proved the effectiveness of minimum cultivation techniques, with or without the use of herbicides, in introducing legumes on natural pasture in the subhumid areas.

Table 1. Suitability of grass and legume species for pasture establishment in Tanzania.

Grasses	Legumes
Humid to subhumid ecological zones	
Setaria splendida	*Neonotonia wightii*
Panicum maximum	*Medicago sativa*
Setaria anceps	*Desmodium uncinatum*
Chloris gayana	*Desmodium sandwicense*
Pennisetum purpureum	*Desmodium intortum*
	Dolichos formosus
Subhumid to semi-arid ecological zones	
Chloris gayana	*Medicago sativa*
Setaria anceps	*Neonotonia wightii*
Panicum coloratum	*Clitoria ternatea*
Panicum maximum	*Dolichos formosus*
Panicum antidotale	*Rynchosia sennaarensis*
Cenchrus ciliaris	*Lotononis bainesii*
	Desmodium sandwicense
	Desmodium uncinatum
	Desmodium intortum
	Stylosanthes guianensis
	Centrosema pubescens
	Macroptilium atropurpureum
Semi-arid to arid ecological zones	
Cenchrus ciliaris	*Clitoria ternatea*
Cynodon plectostachyus	*Centrosema pubescens*
Chloris gayana	*Stylosanthes scabra*
	Macroptilium atropurpureum
	Rhynchosia sennaarensis
	Styosanthes humilis

Many experiments have shown the usefulness of applied fertilizers in improving both the yield and the quality of sown pastures where soil moisture supply is nonlimiting (Owen 1964; Owen and Mukurasi 1973; Marandu et al. 1975). Walker (1973) considered the use of nitrogen fertilizer on sown grass pasture, in semi-arid north western Tanzania, uneconomic and recommended the use of legumes in mixed pastures as a practical way of increasing dry matter and protein yields.

Both the shortage and poor quality of forage during the dry season remain major constraints to livestock production in Tanzania. There have, however, been few studies on forage conservation and the utilization of conserved forages. Some early experiments (French 1938, 1939, 1956, 1957) evaluated the feeding value of various grass hays and silages but, recently, attention has been directed on the use of field crop residues in improving livestock nutrition during the dry season (Kategile 1979; Edelsten and Lijongwa 1981).

CURRENT PASTURE RESEARCH ORGANIZATION

Following the reorganization of agricultural research in 1981, pasture research is undertaken largely by the Tanzania Livestock Research Organization (TALIRO). Two other institutions, the Sokoine University of Agriculture and Uyole Agricultural Centre, also conduct research in various aspects of pastures.

The main areas of research include the following:

Range: Monitoring, improvement by sod seeding, grazing management, and bush control;

Sown pastures: Establishment methods, management, grazing systems, and conservation; and

Crop residues and other low-quality roughages: Nutritive value, methods of treatment, and utilization. In addition, small-scale seed production is undertaken at the various stations.

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FORAGE LEGUMES IN AGROPASTORAL PRODUCTION SYSTEMS WITHIN THE SUBHUMID ZONE OF NIGERIA

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Abstract *Land use in the subhumid zone (SHZ) of Nigeria is rapidly changing as a result of increasing influx of both arable farmers and pastoralists from areas of high density in the country. Because land is owned by arable farming communities, traditional grazing lands tend to be heavily pressurized by increasing settled and nomadic animals. Long-term well-being of the livestock industry in the SHZ will therefore depend on the integration of fodder and crop production.*

Methods of improving fodder through use of Stylosanthes in agropastoral systems is described in the cropping and fallowlands areas. As crop and livestock enterprises are normally handled by separate ethnic groups, the need to demonstrate direct benefits to cropping through adoption of a forage legume in cropping patterns is suggested as an incentive to invest in fodder improvement in arable areas. The need for screening other legumes for agropastoral production systems is emphasized because of the vulnerability of the available stylo cultivars to anthracnose.

The subhumid zone (SHZ) of Nigeria is undergoing rapid change in land use. Although characterized by a satisfactory rainfall (900-1,500 mm) and a long growing season (180-270 days), its ratio of population/land area is low. Until recently, the only significant use of this area has been as a source of dry-season feed for nomadic livestock.

Pastoral production in Nigeria is concentrated in the arid north. But it is constrained by the short wet season. Overstocking has led to a fodder-stock imbalance, which is forcing stock into the SHZ, particularly in the dry season when the tsetse flies retreat southward.

Repeated aerial and ground surveys by the International Livestock Centre for Africa (ILCA) in the SHZ of Nigeria since 1979 have reported higher human and animal numbers than previously estimated (Bourn and Milligan 1983). Migration into the SHZ of farmers dislodged from more intensively farmed and highly populated areas of the country became significant around 1950 and the trend intensified in 1960s. (Agboola 1979). With the apparent reduction in the tsetse fly infestation due to the combined effect of cultivation and government-initiated spraying programs, increasing numbers of livestock tend to stay longer within the zone (Bourn and Milligan 1983). The Sahelian drought must have also contributed to the increase of livestock in the zone.

Estimates by van Raay (1975) suggest that more than half of the Fulani in northern Nigeria are settled or semi-settled. For example, in the SHZ, traditional pastoralists are beginning to settle near cultivated areas. So far, the observed pattern of settlement is that livestock numbers and areas under cultivation tend to be positively correlated until 50% of the land is brought under cultivation (Bourn and Milligan 1983).

According to the Food and Agriculture Organization of the United Nations (FAO 1983), apart from better access to crop residues there are other reasons why pastoralists wish to settle and integrate their livestock with crop production, such as:

(a) The inability to survive on livestock products and revenues because of drought and disease;

(b) Traditional cattle husbandry systems will become more difficult to sustain due to encroachment on grazing land by crop producers;

(c) Cattle movement will be impeded by ribbon development along highways and water-courses that cut across traditional cattle-crossing routes;

(d) Sanctions against cattle movement, such as veterinary quarantines or tolls;

(e) The need to settle to obtain access to veterinary, livestock feed and social amenities, such as education and health welfare facilities; and

(f) Acquiring cattle as payment for herding cattle owned by local farmers.

Because of these reasons, sedentarization tends to be part of a progression from pastoralism to integrated crop and livestock production. In Nigeria, crop and livestock enterprises are most often carried out by separate ethnic groups. But farmers appreciate the food products derived from cattle as well as the manure, draft, and transport benefits that cattle also provide (FAO 1983). Cases of progression from arable cropping to integrated crop and livestock production are not uncommon in the SHZ where farmers tend to invest surpluses from cropping in cattle.

Increased cropping and livestock production, either independently or integrated, will increase the pressure on the limited available land. Dwindling grazing areas and shortening of fallows will be the natural consequence. Continuous cropping, and grazing will rapidly reduce the capability of soil to support grain and fodder production. The potential role of forage legumes in the agropastoral production systems is discussed on the basis of the findings of the ILCA subhumid zone team.

De Leeuw and Agishi (1979) summarized pasture research in Nigeria as follows:

> Although it is true that nearly three decades of research work has generated much useful information on species suitability in terms of yields, quality and persistence as well as on their performance under different types of management, practical follow-up of this work in commercial enterprises has not yet happened. Thus, the identification of research objectives has remained very much the perrogative of the researchers without them

benefitting from feedback from the entrepreneurs in the field.

Because of the presence of trypanosomiasis, the SHZ was not even included in the research program referred to by de Leeuw and Agishi. The ILCA Subhumid Program is not only confined to the SHZ but its research is carried out with the pastoralist, and the ultimate test is the adoption of its interventions by the pastoralist. The Program is following a multidisciplinary livestock systems research approach.

PRODUCTION PATTERNS AND CONSTRAINTS

Present cropping and livestock-rearing methods in Nigeria have evolved through years of trial and error with the objective of providing the producers with an assured level of subsistence. The production systems are adapted to the climatic and edaphic conditions and are suited to the available land, capital, labour, and managerial abilities. Intercropping, involving cereal and grain legumes in various combinations and intensities, is the most common practice. This strategy maximizes land use and return to labour and minimizes risk of total failure as might happen with sole crops (Norman 1979). The area under cultivation is determined primarily by labour available for land preparation; mainly for hand ridging. Delay in land preparation tends to shorten the growing period and minimizes benefit of N flush to crop early in the season (Kowal and Kassam 1978). The soil conditions tend to deteriorate quickly under cultivation and traditionally the farmland is abandoned after variable periods of cropping to a naturally regenerated fallow (Jones and Wild 1975). Fallowing is generally believed to provide the following effects: (a) accumulation and storage of nutrients in above ground vegetation for later release to the surface soil; (b) addition of organic matter to the surface soil, thereby increasing total nutrient and cation exchange capacity; and (c) reduction of crop-associated weeds, pests, and diseases.

The length of fallow required to restore humus after 1 year of cropping at various rates of organic matter addition and decomposition is given in Table 1.

Table 1. Length of fallow required within the crop/fallow rotation at different percentages of equilibrium attained under natural vegetation after 1 year of cropping.

Addition of humus during cropping	Decomposition constant (%)	Humus maintenance (yrs) and years to maintain humus at equilibrium of natural vegetation		
		25%	50%	75%
0	2	0.7	2.0	6.0
	4	1.3	4.0	12.0
	6	2.0	6.0	18.0
33% of fallow addition through crop residues	2	0.2	1.3	4.7
	4	0.9	3.3	10.7
	6	1.6	5.3	16.7

Source: Adapted from Kowal and Kassam (1978).

Prolonged fallows are a very effective means of soil rehabilitation where population density is low (Greenland 1970), but with increasing population and economic pressure fallow periods will shorten or completely disappear in the SHZ (Powell 1984, personal communication) as in the case of the most densely populated parts of Nigeria and other West African countries (Norman 1979). Under these circumstances inorganic and organic fertilizers are used to replenish the soil. As many soils cannot be cultivated without undergoing some degradation, a rest period, i.e., time over which land is not cultivated and allowed to revert to "natural vegetation," is desirable (Shah et al. 1983).

The length of the dry season in the SHZ is variable from the south to the north, and during this period soil moisture reserve is too low to support plant growth. The natural vegetation, which is predominantly graminaceous, does not meet the nutritional requirements of cattle (Fig. 1). Stock that has access to crop residues can derive adequate nutrition during the first 2 months of the dry season (Powell and Otchere 1984, personal communication). However, this will vary depending on the intensity and productivity of crops and the livestock population in the vicinity. Although

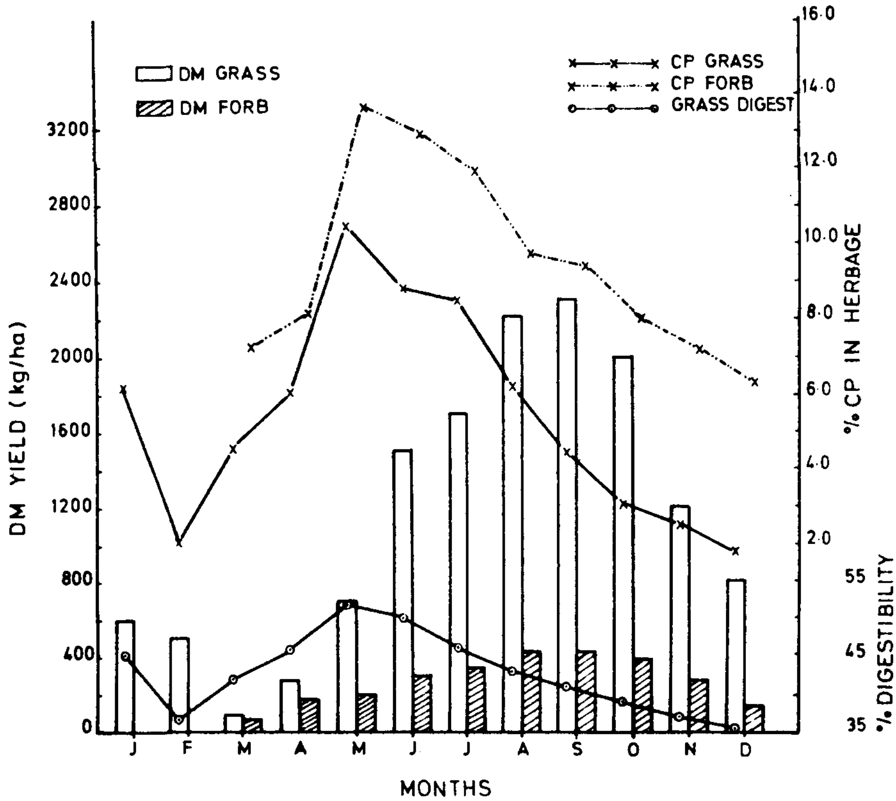

Fig. 1. A generalized productivity and utilization pattern of natural herbage at Kachia Grazing Reserve. (Note: DM = dry matter, CP = crude protein)

supplementation with purchased agroindustrial by-products is the easiest method of overcoming dry-season nutritional deficiencies of livestock, it is not a long-term solution because there are inadequate supplies. Improving the quality of the forage by incorporating legumes is the obvious alternative. Because of their physiological differences, legumes tend to have higher dry-season nutritive values than grasses (Fig. 2). In the natural herbaceous cover of the SHZ the legume content is low (Fig. 1) and, therefore, has to be sown.

Sedentarizing pastoralists tend to adopt cropping techniques adapted from the local farming community. Land used for grazing and cultivation of crops seldom belongs to the pastoralists. Moreover, increased cropping will not only reduce grazing lands but also will

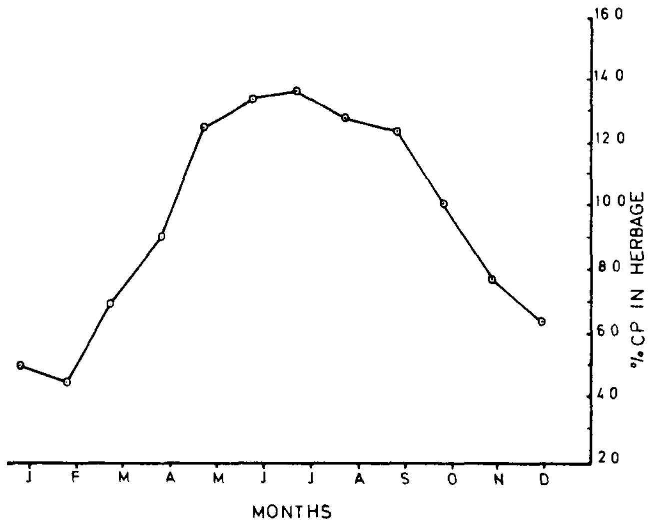

Fig. 2. Changes in crude protein content (%) of Stylosanthes hamata cv. Verano at Kachia Grazing Reserve. (Note: CP = crude protein)

limit the size and quality of the crop land that pastoralists are permitted to use. In these circumstances, pastoralists cannot be encouraged to make long-term investment in pasture improvement.

In Nigeria, pasture improvement has so far been restricted to grazing reserves and commercial ranches. Strip and oversowing on rangelands with legumes such as Stylosanthes spp. and Centrosema spp. have been of limited value because of poor establishment and persistence under communal grazing and indiscriminate annual burning. Furthermore, improvements achieved exclusively on grazing reserves will be inadequate for more than even a small proportion of the cattle, sheep, and goats in the zone. This calls for improved fodder production from crop land also.

Technical options do exist for improving fodder production from the cropped areas. But a farmer who does not own livestock will not be inclined to grow fodder crops unless there is a strong market for it or it is benefical to cropping.

It is evident from the foregoing that with the increase in animal and human populations in the SHZ, nutritional deficiencies from natural grazing and maintenance of soil conditions for sustained cropping will be the major problems of agropastoral systems. However, forage legumes have the potential to improve both livestock nutrition and soil conditions.

USE OF FORAGE LEGUMES IN THE IMPROVEMENT OF LIVESTOCK NUTRITION

Forage Legumes in Crop Mixture

It is estimated that only 22% of the SHZ of Nigeria is under cultivation at present (Bourn and Milligan 1983; Powell 1983, personal communication). Nevertheless, grazing of crop residues accounts for about 20% of the total annual cattle grazing time (Powell and Bayer 1984, personal communication). Cattle selectively graze different parts, starting with immature panicles and leaves of the upper segments of cereal plants. These components, which were of better quality at the beginning of the dry season, make up only about 10% of the total residues, but this is augmented by weed material of above average quality. However, because of the selective grazing the quality of fodder available declines as the dry season advances (Powell and Bayer 1984, personal communication).

Including a forage legume such as Stylosanthes increases the overall crude protein level of the total fodder available after grain harvest of the primary crop. As farmers are used to intercropping, there is a possibility of growing a forage legume with grain crops. The mechanics of growing forage legumes with cereals needs further study. Some of ILCA's work on these lines follows.

The simplest method of introducing a legume is to undersow the cereal crop. However, the time of undersowing is critical to the optimal production of grain and fodder. For instance, planting Stylosanthes guianensis cv cook or S. hamata cv verano on the same day with sorghum reduced grain yield by more than 70%, but the loss of grain yield was minimized if they were sown 6 and 3 weeks, respectively, after planting the sorghum (Table 2). The digestible crude protein (DCP) per unit area of crop residue increased in the presence of Stylosanthes (Table 2).

Table 2. Effect of undersowing stylo on grain yield of sorghum and total available fodder.

			Fodder yield			
Time of sowing stylo	Grain yield (kg/ha)	Grain yield deviation from C_0	Crop residue (kg/ha)	Stylo DM[a] (kg/ha)	Calculated % DCP[b] in total fodder	Available CP[c] (kg/ha)
Unimproved sorghum + S. hamata						
Sole crop (C_0)	1226		7503 (2.4)[d]		-1.09	180
With crop (C_1)	357	-70	1303 (2.5)	4010 (11.4)[d]	5.02	490
After 3 weeks (C_2)	1224		3719 (2.0)	1729 (12.0)	1.78	281
After 6 weeks (C_3)	1287	+5	4260 (2.2)	702 (12.0)	-0.19	179
After 9 weeks (C_4)	1240	+1	3919 (2.3)	408 (12.8)	-0.28	142

Improved sorghum + S. hamata						
Sole crop (C_0)	2192		8796 (2.9)		-0.64	255
With crop (C_1)	480	-78	2367 (1.4)	4334 (12.9)	4.66	592
After 3 weeks (C_2)	1550	-29	3524 (1.6)	3215 (13.6)	3.34	493
After 6 weeks (C_3)	1918	-13	5385 (1.4)	2464 (13.8)	1.42	415
After 9 weeks (C_4)	1980	-10	7463 (2.9)	456 (14.7)	0.01	283

[a] DM = Dry matter.

[b] DCP = Digestible crude protein.

[c] CP = Crude protein.

[d] Values in parentheses indicate actual % CP in the respective fodder.

In another trial, sorghum sown with any of the following legumes -- Centrosema pascuorum, Alisacarpus vaginalis, and Macroptilium lathyriodes on the same day did not suffer significant grain yield reductions as it did with stylo (Table 3).

Sole cropping of cereals is not a common practice. Usually, cereals are grown with grain legumes like soybean. Even under such conditions it may be possible to introduce a forage legume without causing adverse effects on the crops by simple adjustment of plant geometry. Traditionally, cereals and grain legumes are planted on the same ridge (Fig. 3a). Planting two sorghum stands at 0.3 m apart with soybean in between the crop on the same ridge and alternated with ridges of *S. guianensis* cv. cook (Fig. 3b) did not alter plant population of traditional system but offered a good compromise for growing a two-crop one-forage mixture without causing any adverse effects on potential grain yields. This method of planting also substantially increases the fodder quality because of the presence of stylo (Table 4).

Table 3. Grain and fodder yields (kg/ha) of sorghum when planted together with forage legumes.

Type of crop legume mixture	Grain yield	Crop residue	Legume DM[a]	Total fodder
Sole sorghum	1296	4667		
Sorghum + *S. hamata*	313	1685	2778	4463
Sorghum + *S. hamata* cv. cook	388	1555	2063	3618
Sorghum + *M. atropurpureum*	356	2111	1296	3407
Sorghum + *C. pascuorum*	1019	2981	1204	4185
Sorghum + *A. vaginalis*	1092	2519	926	3445
Sorghum + *M. lathriodes*	1297	2741	1481	4222

[a] DM = dry matter.

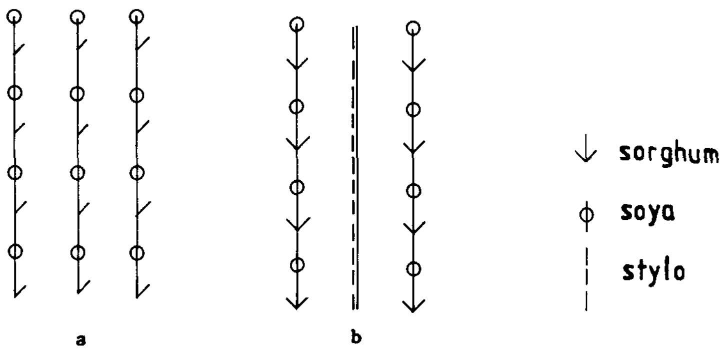

Fig. 3. Crop geometry adjustments to accommodate 2 crops - 1 forage mixture.

Forage Legumes as Supplementation to Natural Grazing

The need for improving natural pastures is well recognized in Nigeria, but no suitable method has been found to do this under the prevailing socioeconomic circumstances. In the SHZ, ILCA identified the following constraints against improvement of fodder resources: minimal labour availability, little or no security of rights over land, and no long-term commitment to land development. A fodder bank concept, which is meant to

Table 4. Grain and fodder yield (kg/ha) of sorghum when intercropped with soybean and stylo.

Grain mixture	Grain yield		Fodder yield	
	Sorghum	Soya	Sorghum	Stylo
Sorghum undersown with soya	1201	91	5170	-
Sorghum undersown with soya + stylo in alternate ridges	1331	68	4813	1360

minimize these constraints, is being evaluated through the various stages of systems research. Fodder banks are concentrated units of forage legumes established by pastoralists adjacent to their homesteads to serve as supplements to dry-season grazing.

The use of forage legumes, such as stylosanthes, to alleviate dry-season nutritional deficiencies has been demonstrated at the National Animal Production Research Institute (NAPRI, Shika, Nigeria). But the primary goal of ILCA has been to develop a low-input technology appropriate to the objectives and capabilities of pastoralists. To this end, a "best bet" fodder bank package was developed for the pastoralists, based on experimental results, experience, and information on baseline data on herd size, availability of legume, its productivity, etc., and literature. This involved the following steps: (a) fencing a block of about 4 ha; (b) preparation of the seed bed by confining the herd overnight in the area; (c) broadcasting scarified seeds; (d) early-season grazing to control fast-growing grasses; (e) allow the forage to bulk up by alternating grazing until the dry season; (f) select the appropriate type and number of animals, and limit grazing to 2.5 hours/day; and (g) ensure adequate seed drop and stubble is left for regeneration. Initial productivity of stylosanthes fodder banks under researcher-managed and farmer-executed trials using this schedule is given in Table 5.

Pastoralists' compliance and response to the fodder bank production noted in Table 5 and management schedules were found to vary as the number of pastoralists involved in the management increased. The following examples illustrate the feedback from pastoralists:

(a) Fodder bank establishment and management -- Overnight confinement of a herd to prepare land for the fodder bank conflicted with adding manure to the crop land. Moreover, pastoralists who prepared their land this way, faced two problems. First, because their herd size averaged only 50 animals, only about 700-1,000 m^2 could be trampled in a 2-3 day cycle; therefore, theoretically, it required more than 150 days for the preparation of the 4 ha. Second, due to the fear of worm infections, the pastoralists were reluctant to graze

Table 5. Stylo productivity and change in quality of fodder banks during 1981/82 and 1982/83 dry seasons.

Fodder bank	Observations[a]	Oct. 1981	Dec. 1981	Feb. 1982	Apr. 1982	Oct. 1982	Dec. 1982	Feb. 1983	Apr. 1983
Experimental (K'Biri)	Total DM/kg/ha	6824				7350			
	% wt of stylo	56.0				55.4			
	Stylo kg/ha	3821				4072			
	Stylo CP %	13.8	10.6	9.2	5.8	13.6	11.0	9.6	8.7
	Stylo CP kg/ha	527				554			
Pastoralist (K'Biri)	Total DM/kg/ha	4191				5742			
	% wt of stylo	68.0				62.6			
	Stylo kg/ha	2850				3594			
	Stylo CP %	13.0	10.4	9.8	7.9	11.4	10.1	9.7	8.1
	Stylo CP kg/ha	370				410			
Pastoralist (Abet)	Total DM/kg/ha	4900				6258			
	% wt of stylo	63.0				58.6			
	Stylo kg/ha	3087				3667			
	Stylo CP %	12.6	11.3	8.9	7.2	11.9	11.2	8.8	7.0
	Stylo CP/kg/ha	389				436			

[a] DM = dry matter, CP = crude protein.

Table 6. Effect on land preparation and seed dressing on stand count/m^2 of S. hamata cv. cook 6 weeks after planting.

Land preparation method	Seed treatment techniques (stand count/m^2) Mixed with sand	Mixed with dung slurry	Insecticide dressing	Mean
1 week overnight confinement of herd	150	76	167	137
2 weeks grazing before sowing	69	99	67	78
2 weeks grazing after sowing	205	176	212	197
Burning in the dry season	45	195	133	108
Mean	117	137	133	

the recently manured areas (to keep fast-growing grass under control early in the growing season).

An experiment that was designed to test ways of avoiding these problems provided alternatives for establishment of fodder banks (Table 6).

(b) Utilization - supplementary grazing -- The dry season in the SHZ of Nigeria usually occurs from mid-October to the end of April. Researcher-managed fodder banks in the 1st year were grazed by selected animals for 2.5 hours after the day's grazing. However, grazing in the evening presented logistic problems to the pastoralists. Hence, some pastoralists preferred the use of the fodder bank in the morning between the hours of milking and preparation to take the animals for grazing, and the recommendation was adopted accordingly.

(c) Regeneration of fodder banks -- S. guinensis cv. cook is a perennial and sets seeds during the middle of the dry season. Grazing before the seeds set and overgrazing at the end of the dry season seriously affected regeneration in the fodder banks. S. hamata cv. verano is an annual and sets seeds well before the onset of the dry season and, therefore, its regeneration is not affected in the subsequent year. Overstocking a fodder bank was also found to seriously affect seed reserve in the soil. Animals licked the seed on the ground. As seed is costly, annual resowing with purchased seed is not desirable. Hence, some pastoralists were advised to cordone off small areas within their fodder banks for seed collection.

The effect of fodder bank grazing on cattle performance is still under investigation. The following results are preliminary indications. In one experimental herd, control cattle that did not have access to fodder banks lost more body weight and their general condition was worse than those that had 2 hours grazing on fodder banks each day. The control animals also suffered 43% mortality as compared to 14% mortality among those that grazed fodder banks for 2 hours/day (Otchere 1984, unpublished).

USE OF FORAGE LEGUMES IN CROP PRODUCTION

Botanical composition of an S. hamata fodder bank was found to change with time. The proportion of more nitrophilous grasses such as Andropogon spp. and Hyparrhenia spp. increased after 3 years as compared to the predominant Loudetia spp. at the beginning and in surrounding areas (Table 7).

At an ILCA experimental site, Kurmin Biri, maize growth and grain yield was much higher, at the respective nitrogen rates, when a portion of fodder banks of different ages was cropped as compared to yields immediately outside the fodder bank, which was previously either cropped or was under natural subclimax vegetation (Fig. 4). Some of the physical properties of the ferruginous soil of the experimental site (major soil type in the SHZ) under these conditions are given in Table 8.

Preliminary experimental results obtained in Table 8 suggest that forage legumes such as stylosanthes

Table 7. Frequency distribution of major grasses in the herbaceous cover of the Kachia grazing reserve.

Species	Natural vegetation	Fodder bank
Andropogon spp.	6.2	13.3
Brachiaria spp.	8.3	-
Digitaria spp.	0.8	-
Hyparrhenia spp.	11.4	16.1
Loudetia spp.	40.7	4.0
Panicum spp.	0.8	-
Paspalum spp.	1.4	0.4
Setaria spp.	0.6	0.8
Pennisetum spp.	-	0.5
Others	24.4	5.6
Legume (*Stylosanthes hamata* cv. verano)		59.3

could improve soil conditions and, therefore, benefit crop production if adopted in a crop rotation. Where long fallow periods cannot be practiced due to more intensive cropping, short-term legume fallows would still be advantageous.

The possibilties of legume-based cropping offer a promising opportunity for integrated crop/livestock production. For a farmer who does not own livestock it

Table 8. Influence of vegetation on some soil physical properties - preliminary results.

Type of vegetation	Ultimate infiltrate rate (mm/hr)	Bulk density
After 3 years hamata	49	1.32
Uncropped area with subclimax vegetation	20	1.77
3 year cropped area	15	Not determined

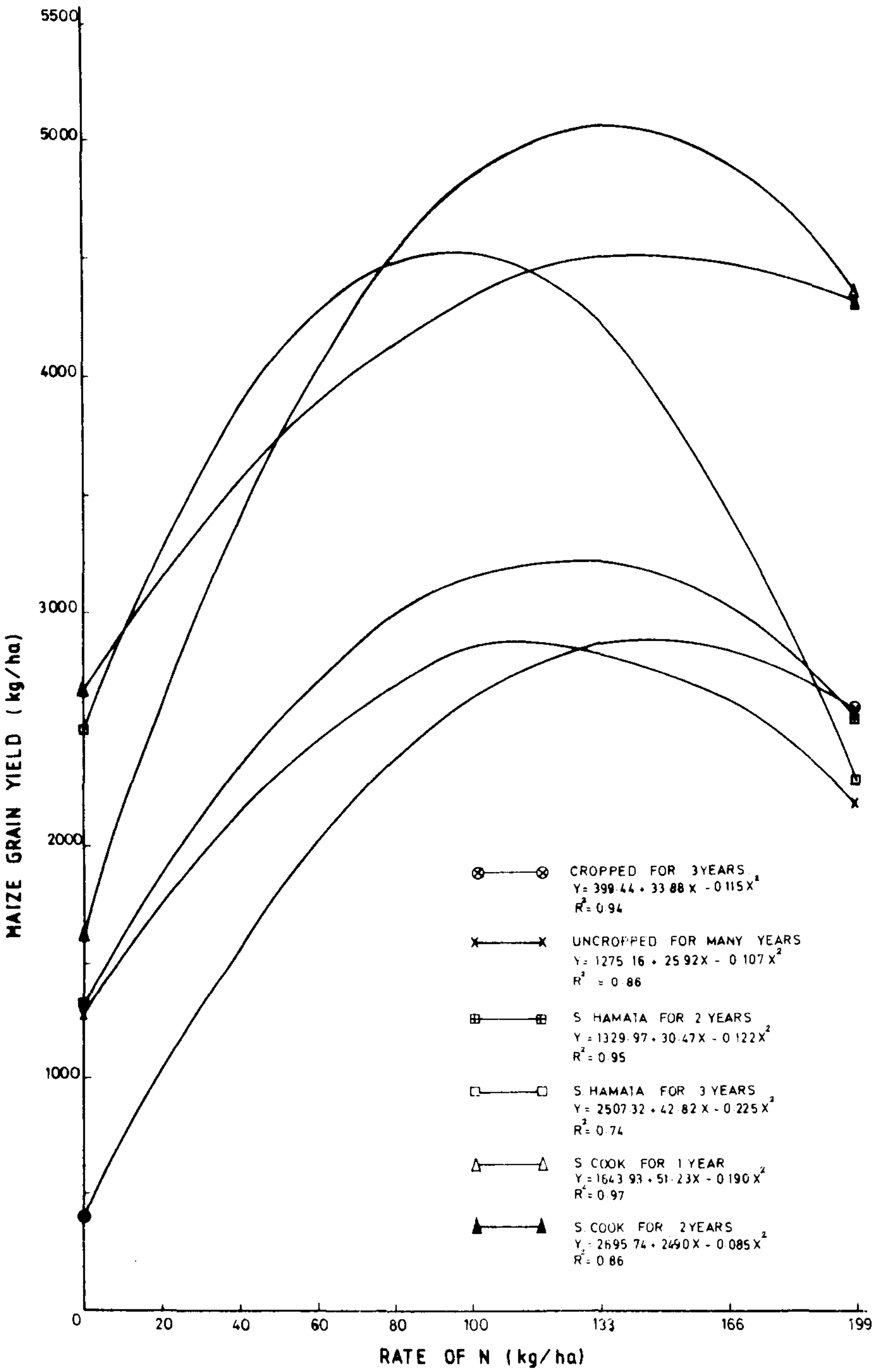

Fig. 4. Effect of N application on grain yield of maize grown on land with different cropping histories K'biri, 1983.

Table 9. Performance of forage accession at Kurmin Biri -- Kachia grazing reserve.

Entries	Accession No.	Approximate date of flowering	Anthracnose rating	DM/ha (mean of 3 = one m^2 plot)	Seed kg/ha	Dry season
Stylosanthes						
humilis		10 July	5	932	79	1.0
scabra		25 Sept	1	1820	72	5.0
guianensis cv. cook		28 Oct	2	3284	138	5.0
guianensis cv. schofield			4	3252	40	-
guianensis cv. endeavour		25 Sept	1	2064	48	5.0
guianensis "tardio"	CIAT1523	4 Nov	1	7066	-	5.0
guianensis "tardio"	CIAT1280	20 Nov	1	7583	-	5.0
guianensis "tardio"	CIAT1283	20 Nov	1	7612	-	5.0
capitata	CIAT1315	26 Oct	1	3344	157	2.5
capitata	CIAT1097	17 Aug	1	3315	84	2.0
capitata	CIAT1405	17 Aug	3	3712	49	2.5

capitata	CIAT1318	9 Sept	1	2730	157	3.5
capitata	CIAT1728	26 Oct	1	3836	61	2.5
capitata	CIAT1342	26 Oct	1	3748	131	3.5
capitata	CIAT1693	17 Aug	3	3450	182	3.0
	CIAT1441		1	2505	34	2.5
	CIAT2044		1	3432	80	2.5
	CIAT1019		1	4147	40	3.0
	CIAT1643		2	3269	77	1.0
	CIAT1582		2	3800	175	1.0
capitata	CIAT2133	26 Oct	2	3669	96	1.0
capitata	CIAT2039	26 Oct	2	4894	115	1.0
capitata		26 Oct				
macrocephala		17 Aug	1	2248	143	3.0
macrocephala		17 Aug				
macrocephala		17 Aug				
macrocephala		17 Aug				
hamata cv. verano		10 June				

Note: Anthracnose rating: 5 lesions - very prevalent with leaf drop, 3 lesions - moderately prevalent with no leaf drop, and 1 - no apparent lesions. Dry season rating based on percentage leaf loss in November: 5 - no leaf drop, 4 - 25% leaf drop, 3 - 50% leaf drop, 2 - 75% leaf drop, and 1 - drop all leaves.

is an incentive to agree to requests from pastoralists for land to establish fodder banks.

FUTURE PROSPECTS

In the SHZ of Nigeria, whatever the experimental benefits from forage legumes, this will have to be extended to farmers with caution because of the narrow legume base that is available at present. Research with forage legumes in Nigeria began about 3 decades ago. NAPRI recommended in 1979 three stylosanthes cultivars; namely, *S. guianensis* cv. cook, *S. guianensis* cv schofield, and *S. hamata* cv. verano for the SHZ. Of these, *S. guianensis* cv. schofield has long been discarded because of its vulnerability to anthracnose. *S. guianensis* cv. cook was free of this disease for the 3 years but it is beginning to show symptoms in some of the trials. Hence, all experimental work and on-farm trials are now restricted to *S. hamata* cv. verano and only occasionally to *S. guianensis* cv. cook. Thus, there is an urgent need for widening the genetic base of forage legumes. Preliminary evaluation of some stylosanthes accessions by ILCA are given in Table 9.

Screening forage legumes for the SHZ has to involve inter- and intrageneric accessions for traits that are required for situations within the agropastoral system. Some of them are: drought tolerance, high N fixation, compatibility with arable crop, persistence under heavy grazing, and high seed production and good establishment when surface or sod sown. But with the rate of migration of both humans and livestock into the zone and the urgency for forage legumes that can help meet the needs of animal nutrition and soil rehabilitation, the development and extension agencies cannot wait for an end to the long search for an "ideotype" that combines all the attributes mentioned. Therefore, ILCA has to work with the best available species while the search for better legumes continues.

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Session II

Pasture Research Methodologies and Regional Networks

COLLECTION AND PRELIMINARY FORAGE EVALUATION OF SOME ETHIOPIAN TRIFOLIUM SPECIES

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Abstract *Between 1982 and 1984 a total of 882 seed accessions of native Trifolium species were collected from the Ethiopian highlands for screening. Initial observations gave yields of up to 6.3 t/ha. Subsequently, three experiments were carried out to assess yield response to P. The best yields were obtained from* T. tembense *(6.8 t/ha),* T. quartinianum *(6.2 t/ha),* T. decorum *(5.7 t/ha), and* T. steudneri *(5.3 t/ha) at 35 and 40 kg/ha P, which were about six times the yields obtained without P. There were no significant species differences without P. At the same time, laboratory analyses on some of the above species gave values of 73.56-74.09% dry matter digestibility (DMD), 19.1-21.3% crude protein (CP). In 1982, a sheep digestibility trial showed that incremental levels of Trifolium in teff and wheat straw significantly increased digestibility. These studies have shown that Ethiopian clovers have good potential for forage production in highland areas with moderate levels of P application.*

Insufficient and poor-quality livestock feed are some of the major constraints contributing to poor livestock productivity. In tackling the enormous shortfall in the livestock feed resources, ILCA is focusing on the use of forage legumes. Not only do legumes provide highly nutritious forage, they also improve soil fertility through biological nitrogen fixation (BNF), thus creating an interphase between agriculture and livestock production in peasant farming through crop rotation or intercropping.

ILCA has programs in the different ecoclimatic zones of tropical Africa. The Highland Program is appropriately located in Ethiopia. These cool highlands present an ecoclimate that is somewhere between temperate and tropical in character. There are large areas with black clay acidic soils subject to seasonal waterlogging and low in available phosphorus and there are incidences of frost at certain times of the year. Initially, it was intended to obtain forages adapted to these conditions that ILCA started the collection and evaluation of native clovers. Since then collection has extended to lowland areas including browse species to look for species that could be adapted to the tropical savannah.

Initially, priority was given to Trifolium because the genus contains several important forage species and preliminary screening in Kenya and later work in Australia indicated the good forage potential of African Trifolium species (Strange 1958; Mannetje 1964). The African clovers are concentrated in the cool highlands and Ethiopia with its massive highland area totaling 490,000 km^2 or 43% of the total for Africa contains 28 Trifolium species (9 of them endemic) out of a total of 40 found in eastern Africa (Gillet et al. 1971, Getahun 1978, Thulin 1983).

Therefore, ILCA's aim was to collect sufficiently variable forage germ plasm from as many environments of the diverse Ethiopian highlands as possible to evaluate their forage potential because initial observations elsewhere in Ethiopia had been favourable (CADU 1972). Nutritional values were also analyzed.

This paper presents observations and experiments carried out from 1981 to the beginning of 1984 on seed collection, DM yield response to P application and nutritive value of Ethiopian clovers by members of the Forage Legume Agronomy Group (FLAG), the Highlands Programme, and the Nutrition Laboratory. The results demonstrate the role of native germ-plasm collection in forage production.

METHODS

Forage Germ-Plasm Collection

Seed collection started sporadically in 1980 and systematic work began in 1982. Exploratory missions were undertaken during the peak of flowering for annuals in August/September, except in the Agaw Medir area of Gojam where flowering was in November, to identify suitable collecting localities. The collection season for annuals was usually between October and November in most areas and December in Agaw Medir, whereas the perennials were usually collected between December and January. Collections were made at 10-km intervals along predetermined routes and also whenever large populations were found. In this way, both wider coverage and sufficient seeds of large populations were obtained for immediate screening. In some cases, the same area was visited twice because of different seed maturation dates even within the same species. Two teams were fielded to different areas at the same time to have wider coverage of material collected at the same ripening period (Kahurananga and Mengistu 1983, 1984).

Yield

In 1981, seeds of T. tembense, T. rueppellianum, and T. decorum were all collected from Shola, Addis Ababa, and T. steudneri, collected from Debre Zeit (1,800 m altitude, rainfall 800 mm rainfall) were planted in plots at Shola for preliminary observations (Kahurananga 1982).

Between 1982 and 1983 three experiments were conducted on the yield response of Ethiopian clovers to P application. All the trials were conducted at Shola (9° 02'N 38° 42'E) at an altitude of 2,380 m. The soil is seasonally water-logged black clay that cracks extensively during the dry season. Soil analysis indicated pH 5.8, 22 ppm N and 8.68 ppm P. Total rainfall in 1982 was 1,100 mm with 683 mm falling during the experimental period between July and October. There was more rainfall in 1983 totaling 1,328 mm with 920 mm falling during the experimental period between May and October. The average maximum and minimum temperatures were 21°C and 11°C, respectively.

The first experiment was conducted during 1982 and 1983. The purpose was to determine the DM yield response of T. tembense and T. rueppellianum to 0, 5, 10, 20, and 35 kg of P ha^{-1} applied as triple superphosphate (TSP) and harvested at 90, 105, 120, and 135 days. The seeding rate was 8 kg ha^{-1} in rows 40 cm apart. Planting was at the beginning of the long rains in July 1982. During 1983, the planting was split into two dates, one during the short rains and the other during the long rains and included T. quartinianum in addition to the other species. Harvesting was done at the same dates mentioned using a wooden frame and samples were taken for estimation of DM yield (Akundabweni 1984).

The second experiment was conducted in 1983. A total of 22 accessions of six annual Trifolium spp. were grown and fertilized at 0 and 40 kg of P ha^{-1}. The clovers were planted at a seeding rate of 10 kg ha^{-1} in rows 20 cm apart in July. The clover accessions were collected from altitudes ranging from 1,850 m - 3,040 m and average rainfall (annual) from 800 mm to 1,500 mm with clay or clay loam soils typically of pH 5.8. Harvesting was done at 50% flowering and samples of estimation of DM were taken as in the preceeding experiment. (Kahurananga and Tsehay 1983).

The third experiment was also conducted in 1983, and T. tembense, T. rueppellianum, and T. steudneri were grown with 0/0, 9/10, and 27/30 kg ha^{-1} N/P applied as diammonium phosphate (DAP) and 10 and 30 kg of P ha^{-1} applied as TSP. Planting was in July at a seed rate of 10 kg ha^{-1} in rows 40 cm apart. Sampling was done at 6, 12, and 18 weeks whereby 20 plants/plot for the first two harvests and 10 plants for the third were dug out, washed, and material separated into aerial parts, roots, nodules, inflorescences, and seeds (Jutzi and Haque 1984).

Nutritional Evaluation

Plant samples were taken during the initial observations at Shola in 1981 and analyzed for CP and digestibility. Also, hay comprised of about 30% T. tembense was fed to milking cows to determine the effect on milk yield.

In 1983, systematic experiments were run by the Nutrition Department. A total of 20 Ethiopian highland sheep in four groups of five were fed on rations containing T. tembense with teff straw, wheat straw, oat hay, or maize stover with the clover constituting 0%, 20-27%, 35%, 50-55%, and 100% (Mosi and Butterworth 1983).

Also in 1983, T. tembense hay was fed in different mixtures with teff straw to growing heifers and their growth compared to that of heifers fed teff straw mixed with nug (Guizotia abyssinica) and their economic returns assessed (Olayiwole, personal communication).

RESULTS

Forage Germ-Plasm Collection

A total of 17 collecting missions were carried out between November 1982 and February 1984, during which a total of 882 accessions of Trifolium species were collected (Table 1) out of an overall total of 1,617. The majority of the clovers were collected from altitudes above 2,000 m. The perennial Kenya White Clover, T. semipilosum was the most commonly collected consitituting 15% of the clover accessions closely followed by the annual T. tembense, which constituted 13%. On the other extreme, only one accession each of T. lanceolatum and T. somalense were obtained. The last two are rare but endemic. In all, a total of 22 species, seven of them endemic, were collected in Ethiopia.

Initial Yield Observations

All four species tried at Shola in 1981 grew well. The best yield was given by T. tembense which produced up to 6.3 t ha^{-1}. T. rueppellianum also yielded well giving 5.2 t ha^{-1} (Kahurananga 1982).

Yield Response to P

In the first experiment, P had a very significant effect on the yields of all the three species (P 0.001). The highest yield was 6.2 t ha^{-1} given by T. quartinianum at 35 kg of P ha^{-1} harvested at 120 days. T. tembense gave 5.4 ha^{-1} at the same P fertilizer level

Table 1. Accessions of Trifolium seeds collected from the Ethiopian highlands from 1982-84.

Species	Accessions from each elevation range (m)				
	1500	1500-2000	2000-2500	2500-3500	Total
T. acuale	-	-	-	5	5
T. arvense	-	-	2	1	3
T. baccarinni	1	26	16	8	51
T. bilineatum	-	14	16	2	32
T. burchellianum					
var. johnstonii	-	3	11	27	41
var. oblongum	-	-	-	8	8
T. calocephalum	-	-	-	13	13
T. cryptodium	-	-	16	48	64
T. decorum	-	6	26	12	44
T. lanceolatum	-	1	-	-	1
T. mattirolianum	2	33	10	-	45
T. multinerve	-	-	5	10	15
T. pichisermolli	-	-	15	19	34
T. polystachyum	-	7	17	8	32
T. quartinianum	-	8	13	-	21
T. rueppellianum	-	15	43	22	80
T. schimperi	-	3	16	5	24
T. semipilosum	-	6	70	56	132
T. simense	-	-	21	34	55
T. somalense	-	-	1	-	1
T. spananthum	-	-	-	2	2
T. steudneri	-	16	45	-	61
T. tembense	-	7	50	60	117
T. sp.	-	1	-	-	1
Total	3	146	391	342	882

Source: Adapted from Kahurananga and Mengistu (1983, 1984).

and harvest date. DM yield increases were more pronounced in *T. tembense* than *T. rueppellianum* at increasing levels of P (Akundabweni 1984).

Similarly, the fertilizer effect was very significant in the second experiment ($P<0.001$). There were significant differences between accessions ($P<0.01$). Interspecific yield differences were slightly more significant than intraspecific ones ($P<0.1$). The highest yield was given by *T. tembense* ILCA 8501, which produced 6.8t ha^{-1}, whereas the control from the same species ILCA 5774 produced 5.8 t ha^{-1}. The highest yields of *T. tembense*, *T. quartinianum*, and *T. decorum* were significantly higher than the highest yields of *T. rueppellanum*, *T. schimperi* and an unidentified species ($P<0.01$). There were no significant differences under no fertilizer treatment (Kahurananga and Tsehay 1983). Maximum yields of each species are shown in Table 2.

Even in the third experiment, where whole individual plants were measured, there were significant responses to P application. The addition of 30 kg of P ha^{-1} increased DM yield of individual plants six-fold by the 12th week; root-weight three-fold, and twice the number of nodules. Seedling establishment was faster with the addition of N but N tended to retard inflorescence formation and the number of inflorescenses per plant was reduced at the higher levels (Jutzi and Haque 1984).

Nutritional Value

The results of laboratory analysis are given in Table 2. CP ranged from 19 to 21.3% and in vitro DMD ranged from 73.6 to 75.9%. Hay composed of 30% *T. tembense* increased milk yield of lactating cows by about 10% (Kahurananga 1982). In the digestibility trials with sheep, preliminary results show that incremental levels of Trifolium in teff and wheat straw increased overall digestibility (Mosi and Butterworth 1983). The results of the trial comparing the effect of *Trifolium* and nug *Guizotia abyssinica* meal are still being analyzed, but indications show favourable economic returns with clover (Olayiwole personal communication).

DISCUSSION

Native Germ Plasm

ILCA has now accumulated valuable germ plasm of hitherto uncollected Ethiopian clovers. This is especially true in the case of endemic species, namely, T. decorum, T. mattirolianum, T. pichisermollii, T. schimperi, T. calocephalum, and T. spananthum. Also, T. semipilosum varieties intermedia and brunelli are confined to Ethiopia. Even with the other species found throughout eastern Africa, Ethiopian ecotypes or land races represent new material.

The forage germ-plasm collection activities have given practical experience to staff. Practical problems, such as differential seed maturation dates in the same species and localities, same maturation dates in different localities, differences between annuals and perennials, sampling procedures, mixed species, recognition of species, how much field data is necessary, handling of collected material, and storage and data processing and allocation of time to different activities, only become apparent with experience.

Potential Use

The trials at Shola have clearly demonstrated that some of the annual clovers from the Ethiopian highlands have good potential for hay production on sites with acidic soils subject to seasonal water-logging with moderate inputs of P fertilizer. The most promising species are T. tembense, T. quartinianum, T. decorum, T. steudneri, and T. rueppellianum. The first and last two species showed promise in preliminary screening in Kenya (Strange 1958). Similarly, T. tembense and T. ruepellianum each gave top yields of 6.3t/ha^{-1} in preliminary observations in Ethiopia (CADU 1972). The yields of the other two species were evaluated for the first time. These results are comparable to Vetch, Vicia villosa ssp. dasycarpa, an annual exotic forage legume adapted to the Ethiopian highlands from which average yields of up to 5.2t ha^{-1} have been obtained (Haile 1979).

All the clovers tested showed a dramatic response to P, thus indicating that they are adapted to moderate levels of P found in some sites in the bottomlands. The response shown by T. tembense tend to suggest that incremental yields could be obtained at levels of P above 40 kg ha^{-1}.

Table 2. Top average dry matter yields, chemical composition, and in vitro DM digestibility of seven annual Ethiopian Trifolium species grown at Shola, Addis Ababa in 1981-83.

Species	DM yield (t ha-1)	Phosphorus Input (kg ha-1)	% Crude Protein	% in vitro DM digestibility	Source
T. decorum	5.8	40	19.8	76.00	Kahurananga (1982); Kahurananga and Tschay (1983)
T. quartinianum	6.2	35	-	-	Akundabweni (1984)
T. rueppellianum	5.2	Barn site	19.0	75.88	Kahurananga (1982)
T. schimperi	2.9	40	-	-	Kahurananga and Tschay (1983)
T. steudneri	5.3	40	19.1	73.56	Kahurananga (1982); Kahurananga and Tschay (1983)
T. tembense	6.8	40	21.3	74.09	Kahurananga (1982); Kahurananga and Tschay (1983)
T. sp.	1.5	40	-	-	Kahurananga (1982); Kahurananga and Tschay (1983)

Clovers collected from different parts of the highlands nodulated well at Shola where similar species naturally occur, which means that Ethiopian species are not specific in their rhizobial requirements. It remains to be seen if these clovers will modulate effectively in other parts of East Africa where similar species occur and vice versa. However, African Trifolium species are known to be very specific in their rhizobial requirements (Norris and Mannetje 1964). Therefore, the use of native clovers from Ethiopia or elsewhere from the highlands of eastern Africa outside their normal habitats would most probably require inoculation with appropriate rhizobia as is the case with Kenya white clover in Australia (Jones 1981).

The high nutritive value of the Ethiopian clovers means that they can be blended with low-quality grass hay to improve overall feed quality. It has been shown by the nutrition experiments that a maintenance roughage of 40-50% digestibility could be increased to a production ration of 60% digestibility with the addition of Trifolium with the latter consituting 30% (Mosi and Butterworth 1983). This high-quality could then be used for increasing milk production in cows.

Introduction into Smallholder Farming Systems

Annual forage legumes could fit into peasant farming systems either through intercropping or crop rotation. In large areas of the Ethiopian highlands where low-growing cereals, namely teff, *Erogrostis tef*; wheat, *Triticum aestivum*; barley, *Hordeum vulgare*; and oats, *Avena sativa* are grown, clovers could be introduced by crop rotation. This is the system farmers are used to as is the case when they grow horse beans, *Vicia faba*; chick-peas, *Cicer arietinum*; field peas, *Pisum sativum*; and lentils, *Lens esculentum*. Intercropping could be introduced in those areas of the highlands with taller cereals such as sorghum, *Sorghum vulgare*, and maize, *Zea mays*.

Furthermore, Trifolium introduction would find easier acceptance where farmers are already aware of its nutritive value and contribution to soil fertility. The Agaw Medir of Gojam is such a place. T. decorum grows there extensively in dense swards where it is grazed after flowering. The clover falls into a natural crop rotation with teff, barley, wheat, finger millet, Eleusine coracana; and nug. In this area, the clover plays a very strategic role in boosting grain yield through biological nitrogen fixation. Soil samples taken during seed collection from this area gave persistently high levels of N. This confirms earlier observations where results of a countrywide soil survey gave consistently high N values for soils from Agaw Medir (Murphy 1965).

Finally, the success of introducing forages into African peasant farming systems will ultimately depend on financial returns. The statement that "... cultivation of high quality herbage plants in the tropics can meet with success only if the cost of their establishment and maintenance is justified by an adequate return. To make a planted or sown pasture pay, the animal that grazes it should have the potential to match the quality of the herbage." (Bogdan 1966) could not be more true. In our context, it means that high quality forage could only be grown where there is a profitable dairy enterprise as has been amply demonstrated in different parts of eastern and southern Africa. A dairy enterprise is an absolute prerequisite for forage cultivation in Africa.

The results obtained by ILCA at Shola have shown that native legumes have an important role to play in improving forage production. A collaborative collecting mission between ILCA and CIAT will be completed soon in Kenya and it is hoped that missions will be arranged with national governments to the remaining countries in the near future. The acquired material would then be tested at different sites within eastern and southern Africa through the proposed forage network.

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THEORY AND PRACTICE IN FORAGE GERM-PLASM COLLECTION

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Abstract *The collection of forage germ plasm requires careful planning so that the sampling of plant variation both within and between environments is efficiently accomplished. Plant variation is acquired by sampling larger numbers of sites across more environments and greater distances. Observational data on the plant and environmental data on the site of accession are valuable in that they can reduce the effort required in screening.*

COLLECTION THEORY

Improvements in tropical and subtropical forage productivity have depended largely on the identification of natural genotypes of grasses and legumes that are productive and persistant under economically viable management systems. However, the variation in many species of known forage value has been little explored and a great number of other species with forage potential have received no attention at all. Collection is thus an important tool for the improvement of forage production.

Collection of germ plasm is necessary when appropriate germ plasm of the range of variation desired for testing for specific environmental and management conditions is not available from commercial sources or existing collections of experimental material. It is undertaken in response to a direct request or in return for germ plasm supplied by an institution, as a scientific study to determine what germ plasm is available and what variation is present, to preserve germ plasm of potential forage value that is threatened with extinction, and to form a representative collection for breeding or for future use.

Value of the Germ Plasm Pool

Work on the evaluation of the forage potential of natural genotypes has barely begun. Little genotypic evaluation has been done on even the commercially important species of tropical grasses. A recent list of tropical herbaceous and browse legumes of potential or actual commercial value on which some research had been done contained 143 species (Skerman 1977), while an estimated 3,800 species have potential forage value (Williams 1983).

Africa is the continent with the largest number of endemic grass genera and, thus, is the most important centre of grass variation. The vigorous growth, response to fertility, and resistance to grazing of many of these African genotypes has made them the most successful forage grass species in the subtropics and tropics of other continents, most notably in the Americas and Australia (Parsons 1972; Harlan 1983). In many areas, such genera as *Panicum*, *Hyparrhenia*, *Brachiaria*, *Cynodon*, and *Digitaria* are sufficiently well adapted and aggressive to have become widely naturalized. Clayton (1983) noted that 27 out of 45 important tropical grass species have their distribution centred on Africa, seven are centred on the Americas, and the Mediterranean and Asia have one each.

Although the primary centre of tropical legume diversity is Central and South America (Williams 1983), Asia and Africa are important secondary centres of diversity. Africa is a centre of origin of such commercially important legume genera as *Neonotonia*, *Aeschynomene*, *Lotononis*, *Macrotyloma*, *Lablab*, *Vigna*, and *Trifolium* (Harlan 1983; Thulin 1983). Other agronomically important genera that are represented in Africa include *Stylosanthes*, *Desmodium*, and *Zornia*.

Characteristics of Forage Plants

A good pasture plant must be productive, aggressive so as to rapidly colonize the area in which it is sown, and be capable of persisting and retaining its dominance despite invasion and competition by native flora. It must propagate easily, produce seed readily and in quantity, be adapted to the climatic and edaphic environment of the target area, be resistant to pests and diseases, persist and retain its leaves under periods of drought, and be resistant to cutting, trampling, or grazing and yet have some degree of palatability. It should be productive under low fertility but also respond to fertile conditions. The ability to be used for other purposes than forage is an advantage, e.g., for human nutrition, thatching, fuel.

Plants for cut and carry or carefully managed grazing can have good palatability but in mixed grass-legume swards that are not carefully managed the legume should be no more palatable than the grass so that it is not grazed in preference and, thus, eliminated from the sward. Lower legume palatability is also an advantage in establishment when oversowing grass swards and in the conservation of fodder as standing legume hay for a dry season when its high nutritional value will enable low-quality grass to be more efficiently digested by grazing animals.

Identification of Collection Areas

Plant collection and introduction is based on the general premise that plants will grow successfully in environments similar to those in which they were collected (Burt and Reid 1976; Burt et al. 1976, 1979; Reid 1980). Experience has shown that this is usually the case. Plants also frequently do better in similar environments geographically distant from their origin (Burt and Williams 1975). This is presumably due to their removal from diseases, pests, and competing vegetation that have evolved at the same time. Examples of such successful movements of plants include alfalfa (*Medicago sativa*) from the Mediterranean region to the Americas and Australia, *Stylosanthes humilis* from tropical America to Australia, and *Panicum maximum* and *Hyparrhenia rufa* from Africa to Central America. Thus, productive forage germ plasm for research programs in Africa should be sought not only in the program area but also from geographically distant areas including those on other continents. It also follows that germ plasm that is unsuccessful in one region may be very successful elsewhere.

However, once pests or diseases have evolved or been introduced, the productivity of the introduced germ plasm can be severely curtailed. The introduction of alfalfa aphids to the USA and Australia has severely affected alfalfa production and necessitated the establishment of screening programs to locate resistant germ plasm for breeding programs. The introduction of anthracnose (*Colectotrichum gloeosporioides*) to Australia severely affected the productivity of sown and naturalized stands of *S. humilis* and has essentially eliminated it as an important forage species.

Tropical environments are extremely varied. Factors such as amount of rainfall, length of dry season, altitude, and soil pH, texture and fertility are all important when selecting areas for collection, or sites for the testing of accessions. Although most plants have some degree of adaptability and can grow in a range of environments, the range of environments in the tropics is so large that careful examination is required to determine in what part of the range of each factor a plant would be expected to be productive. Because of the large numbers of accessions currently in collections, it is important to pay attention to the environment of origin when collecting so that all accessions do not have to be tested in all environments and, at least initially, can be tested in environments in which they are likely to be successful.

Because newly cleared or ploughed areas are disturbed environments and grazing and cutting maintains swards in a subclimax or disturbed condition it is not surprising that the aggressive plants required as forages are commonly found in subclimax vegetation and disturbed sites. Climax vegetation in contrast can be less aggressive and persistent (Harlan 1983). The edges, ditches, and margins of roads are the most commonly disturbed sites seen on collection trips; however, the environments and germ plasm present may have little in common with the adjacent, less altered environments. Although there may be species present that have invaded such disturbed sites from adjacent environments it is common to have a high proportion of germ plasm that has been transported from elsewhere.

Sampling Strategy

The sampling strategy adopted by a collector will depend upon the aims of the collection. These can be categorized as: (a) a general collection, a survey to sample the variability in the germ plasm present or to preserve variability of germ plasm threatened with extinction, in an environment or environments; (b) environmental collection, collection of species that occur in a specific environment; and (c) specific species collection, the collection of one or more species of known or potential forage value.

In general collection, to sample variation, transects are made across the environment or environments concerned. Collection stops are made fairly regularly along the transects, modified by environmental considerations. Stops are made in areas where several environments can be examined at once, and an effort is made to sample all of the environmental variation present in the area being collected.

General collection forms a continuum with environmental collection because a specific environment may be defined broadly, over a substantial area; for example, areas with a 4-month dry season, or narrowly, with collection limited to a few, small locations such as areas of Vertisols with a 4-month dry season. In the latter case, transects are done of these target environments across regions with each target environment on the transect being transected in turn, or environmental variations sampled within it.

In collection of specific species, transects are made across the environments where the species is known to occur. To determine the adaptability of the species, collection is also done in other environments that occur within, or adjacent to, the environments of known occurrence.

In practice, there is an overlap of these strategies. In general collection, species of known or suspected forage value are given more attention than those of unknown value, and more attention is given to environments where these are likely to occur. When specific plants or environments are collected it is unusual not to do some collection of other interesting or unknown species and adjacent environments. Normally, such plants are collected at stops whether or not the target species is present. In time, plants that are toxic, not grazed, or of no agronomic interest will be identified and ignored. Thus, serendipitously, the flora is sampled and, in time, fairly good collections of forage germ plasm will result that have at least some representatives of most plants of potential value.

Collection transects should be chosen carefully in relationship to the goals of the collection mission. Some environmental factors of particular importance are total annual rainfall, length of dry season, growing season temperatures (mean temperature, lowest monthly mean minimum temperature, and frost occurrence), soil type, texture, pH, drainage, and fertility.

Numbers of Plants Sampled per Site

Collection is done to acquire the useful variation in germ plasm of specific plants or groups of plants. It is pertinent then to know how many plants of each species should be collected at a site to acquire representatives of at least the more common genes.

Most tropical legumes and grasses are apomictic (self-fertile) with little outcrossing. If useful genetic variability is defined as alleles at a locus with a population frequency of greater than 5%, conservatively, 50-100 plants should be sampled per species per site. Outcrossing species, such as the highland perennial Trifolium, require seed from fewer individuals. A truly self-incompatible, random mating plant would, theoretically, require a sample of only 100 seeds from any plant (Marshall and Brown 1983).

These theoretical numbers of plants are, in practice, only occasionally found at one site, particularly in the case of legumes. As well, a site may have a variety of edaphic environments or distinctive plant phenotypes. These are usually collected separately. The norms for sampling accessions of tropical legumes are: one plant, a few plants more or less in a group or adjacent groups, or a few widely scattered plants. If the plants are self-fertile, it can be assumed that all of the plants in one group are likely to be similar, if not identical. More broadly scattered plants are likely to have more variation, but they too may be essentially identical and considered to be one accession.

Due to environmental factors, the appearance of plants at the collecting site cannot be used with any assurance to predict genetic similarity or variation. Plants that are similar when collected can be quite dissimilar when tested under uniform conditions, and the converse may be true (Schultze-Kraft 1979b).

When variation in edaphic environment or in phenotype suggests genotypic variation may be present, it is probably simpler to collect the variations as separate accessions, recording the observed distinctive characters. If the suspected variations are all put into one sample it will require particularly careful attention in the screening phase to differentiate the variations present within the accession, and these may not show up under the screening conditions. Accessions that are relatively uniform genetically are easiest to screen and describe.

The emphasis in collection of variation is better put into collecting more sites and environments than achieving the theoretically optimum number of plants at one site (Reid and Strickland 1983).

Amount of Seed per Accession

Because collecting is done to acquire variation in germ plasm and few accessions will be considered sufficiently promising to develop immediately (perhaps one in a thousand) it is inefficient to collect more seed at one site than is required for a plot or a few pots for initial evaluation, description, and multiplication. The International Livestock Centre for Africa (ILCA) uses up to six potted plants for initial multiplication and up to six spaced plants in a plot for initial evaluation.

One or more seeds is sufficient for a collection; 20 may be adequate but more than a few hundred can be a waste of time. If an accession is particularly promising and rapid multiplication is desired, more rapid than can be achieved by ordinary means, the original site can be re-collected to acquire a bulk sample.

Number of Accessions in a Collection

There is no single rule as to what number of accessions should form a "collection." Much depends on the amount of variation that is found in a species, or area, the variation in environments in which a species occurs, and the demand for different genotypes to broaden the range of adaptation or to fulfill a specific role.

Enough germ plasm of a species has normally been collected when survey collections have been done over its range at appropriate times of the year and the material collected has shown no particular promise; when a species has been shown to have no agronomic value; when other species are given priority and, thus, germ plasm of an originally important plant is solely collected when it appears at a collecting site (which in practice is only occasionally in this phase for plants which are very common), and when there is more germ plasm collected than can be handled in 1 year. No special effort is made to collect numbers of species with no apparent or unknown value. A particular species must compete with other species of potential for the collectors attention, thus, the numbers that constitute a collection of a given species are directly related to its agronomic interest.

Species that are of primary interest such as *Stylosanthes fruticosa* should be collected on transects throughout its range, to the extremes of its environmental adaptation. If on screening variation is noted, further collection can be done in areas of interest to attempt to sample the extent of the variation. When specific collections of species of agronomic importance are collected to locate resistance to diseases or pests, e.g., anthracnose in *Stylosanthes*, the question of numbers of accessions is less important.

Rate of Collection

Collection is normally done at a rate determined by the interest in the species to be collected, the frequency of occurrence of the target species, the ease of access to the collection area, the stamina of the collector, the money and time available, the length of the collecting season, and the capability of the supporting infrastructure to accession, multiply, evaluate, and store the material. Large forage research centres handle 1,000 to 2,000 lines a year.

Data Recorded at the Collection Site

For early collections, field notes were written that included such environmental and other data as the individual collector felt were important in relation to the particular research program and target environment. Numbers of accessions were small and notes tended to be brief.

With much larger numbers of accessions and the wide testing of collections, information on the accession and the environment of collection has become much more important because not all lines can be tested at all sites, and such information reduces the amount of screening required (Burt et al. 1979). The availability of computers has made the handling of such data readily manageable. Thus, the demand these days is for more data rather than less.

Important environmental factors that should be recorded include those of climate, soil, associated vegetation, imposed management, disturbance, and incidence of pests and diseases. A precise description of the location is required so that the site, or particular plant, may be re-collected if necessary, and so the information obtained from climatic and edaphic maps will be as accurate as possible (Reid and Lazier 1979; Isabell and Burt 1980; Reid and Strickland 1983).

Legume/Rhizobium Association

The Rhizobium/plant association is an important factor in the value of legumes as forages because the associated bacterium provides the plant with atmospheric N in a useable form. Plants may readily form nodules with rhizobia commonly found in the soil, in which case they are referred to as belonging to the "cowpea group." Many pasture plants, however, have requirements for specific rhizobial species or genotypes, and when moved to a new area there may not be such appropriate rhizobia present. The plant will, thus, produce much below its potential. This specificity of requirement may be generalized within genera (e.g., Desmodium) or may be specific for a genotype within a species that is normally broadly associative (e.g., Sxylosanthes guianensis as a species generally nodulates with the cowpea group of rhizobia, however, the commercial cultivar of S. guianensis, cv. Oxley, has specific requirements). Laboratory tests have shown that even members of the cowpea group can show significantly better growth with certain Rhizobium strains (Gibson and Brockwell 1968; Mannetje 1969; Trinick 1982).

It is apparent then that rhizobia should be collected for each genotype; however, few countries have the facilities and staff for propagation, storage, and testing of this germ plasm and fewer could handle the numbers involved. Perhaps a compromise that is better than no collection or too large a collection of nodules is to collect them from species of particular interest in distinctive environments. As far as tropical and subtropical forage Rhizobium are concerned, the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) and Centro Internacional de Agricultura Tropical, Colombia (CIAT) are two organizations that are interested in and have facilities capable of handling some lines, and the FAO-funded MIRCEN group may be able to handle some as well.

COLLECTION TRIP

Reference Material

To ensure that the trip is efficient, producing useful and varied germ plasm with the least expenditure of time and money, careful planning is required (Schultze-Kraft 1979a; Reid and Strickland 1983).

Herbaria should be visited because they can provide information on what species and germ plasm are available and where and when the collection should be done to acquire ripe seed. Not only specimens of species with known forage potential should be examined but also a search should be done through the genera to locate new species and genotypes with forage potential.

Topographic, climatic, and soil maps should be used to identify regions for collection with elevation, climates, and soils similar to the target environment or, in the case of survey collections, to plan routes that transect environments. Important climatic factors include the mean growing-season temperature, minimum temperatures in the growing season, frosts, length of the dry season (or growing season), and rainfall. Soil factors of particular importance are pH, texture, depth, drainage, and fertility.

These environmental factors will influence the genotype present and the likelihood of its adaptation at the target area. Land-use maps will detail current utilization of the target areas or transects. Areas that are grazed are likely to have grass and legume species and genotypes adapted to survival under grazing, whereas high rainfall forest areas have more climbing vegetation that is better adapted to cut and carry. Long-established road margins and fields usually have a greater variation in species than newly cleared areas. Introduced species are found in these areas, although some of the species originally native to the area may have disappeared due to clearing or grazing.

People with local knowledge should be consulted, botanists who have collected in or studied the region, agronomists who have worked in the area, and people who have visited the region or who live there. These contacts should be able to answer questions on the ecology, farming systems, accommodation, and roads. The more information that is available before a trip, the better equipped the collector (Appendix 1) and the less arduous and more successful the trip.

Administrative Organization

Permission for the collection trip should be obtained from the government concerned well before the trip begins. Care must be taken that the objectives of the trip and the locations where collections will be made are well described and a time table is provided. Travel permits may be required for travel in some areas, other areas may be closed to travelers. For those working within the government services of the country in which the collection is to take place, such permissions should not be difficult to obtain. Letters of introduction should be acquired, particularly to government authorities; these may be particularly useful when the mission runs into difficulties. All conditions set by this government should be carefully met. For example, half of the seed may have to be left with a national program, or the seed may have to be multiplied before any leaves the country. In cases where half the seed has to remain, when there are 20 seeds or less, the collecting organization is normally allowed to take all of that line to multiply it, returning an agreed amount to the country of origin.

Arrangements should be made before the collection trip for multiplication, long-term storage, and agronomic description and initial evaluation of the germ plasm collected.

Time of Collection

The time of the year chosen for collection will be largely determined by the expected time when mature seed will be available of the species of greatest interest. Many other species will not have ripe seed at that time. Thus, it is important to record at each site the other legumes present and whether they have shed their seed or whether they as yet have only green seed. This will help plan future trips to collect these lines in a period of the year when they are ripe. The same locations can then be collected. When there is no mature seed, seed may be found on the ground, or vegetative material may be collected.

Staff Considerations

There is little reason why one person cannot form a collection expedition. That person should be at least at a graduate level or be a technician with several years experience, familiar with forages and with their utilization, and preferably with some exposure to the methodologies of experienced collectors.

One particularly good reason for having a second person on a collecting trip, however, is that the trip and the collection can still continue if one member is tired or ill. The second person can be a technician who should be able to drive, assist with soil and rhizobial sampling and seed collection, or can be another collector, a local counterpart, or even a soil scientist who can be of assistance in recording the environmental data.

The personal health of the staff is an important factor on collection trips because illness can ruin a collection trip and delay a program for a year. Collectors should not exhaust themselves, should take care that proper rest and food are taken, and that precautions are taken against intestinal and other diseases.

Route

As access limits the efficiency of collection, the collection route and collection stops are planned by superimposing the soil, climate, altitude, land use, and herbarium data on a detailed road map. This is not to suggest, however, that collection is to be restricted to main roads. Side roads, farm roads, and tracks should be utilized. In regions that have few roads, collection of important environments must be done by horse, mule, donkey, or on foot. The route is planned to include as many target environments and transects as possible.

Collection Stops

The method of selecting collection sites varies with the environmental variation and the sites to be collected. Basically, there are three methods: (a) stopping along a route at regular intervals, (b) stopping only at locations of interest or of variation, and (c) some combination of (a) and (b). The number of collection stops in a given distance of road will depend on the distance that has to be traveled in a day. In practice, an 8-hour collection day is sufficient to exhaust most collectors, and the energy and enthusiasm wanes rapidly as the day is prolonged, fewer notes are taken, and the quality of the work deteriorates. Even over shorter distances, about 13 stops a day is probably a maximum.

If the stops are chosen by distance, then stops are usually made at locations where there is some environmental variation and several locations can be sampled at one site, i.e., a plain (the dominant feature), a valley wall, a river bank, and areas with and without grazing and wetter and drier areas.

Legumes may occur in considerable abundance at certain locations and be completely absent in adjacent locations with apparently identical environmental conditions. Thus, when a collection stop is made and there are no legumes at the road edge, in fields, or in the nearby environments, then the location and environment should be briefly recorded as well as the fact that there were no legumes present. Other stops should be made in the vicinity, in spots where there are environmental variations. Legumes can usually be found after two or three such brief stops. For efficient collection, a well-organized daily routine is required (Appendix 2).

The Data Sheet

Both simple and detailed observations at collection sites have been described previously (Reid and Lazier 1979; Reid and Strickland 1983). ILCA in the past has used a generalized collection sheet (Appendix 3), but has, with the initiation of a computer program to handle the data, moved to a more detailed collection sheet where specific questions are asked and are organized in the same manner as the computer data base. Not all questions will be relevant or answerable at a given site. However, the more information that is recorded the more likely it is that an accession will be tested in an appropriate environment. The data sheet and the definitions of the data to be collected are presented in Appendix 3.

Although much information can be obtained by observations made at the collection site an important but often neglected source of information on the forage value of native plants is the local farmer or grazier. This is particularly true in Africa where livestock owners are usually closely associated with their animals. Local information is especially useful for browse species because the screening of these is much more difficult than that of herbaceous legumes or grasses and several years growth is usually required to obtain basic information.

Although information from one farmer may be misleading, conversations with a number of farmers will provide more reliable data because it is common to find a species considered to be unpalatable in one area yet be quite acceptable fodder in another. Such variation may be due to the availability of alternative fodder in times of stress.

Collection of Rhizobium

A critical factor in the collection of Rhizobium germ plasm is that most seed collection is done in the dry season when the soil may be impermeable and the plant roots difficult to excavate. Also, nodules are sloughed by the plant in the dry season and there may be no viable nodules present to collect. If this is the case, and if warranted, the collection sites should be returned to in the wet season and nodules collected at that time. The soil should not be too wet because rhizobia do not thrive in saturated soils.

The actual collection is a simple matter. Sealable vials have a small quantity of dessicant (anhydrous $CaCl_2$ or silica gel) put in and held at the bottom by a light wad of cotton wool. Ten to fifteen nodules ideally are collected from each plant, cut from the root about half a cm on each side. The volume of the plant tissue should not exceed that of the dessicant, which should be about 25% of the volume of the vial and the vial should also be labeled. ILCA staff use the plant accession number with an R prefix to identify the Rhizobium, however, a separate numbering system may be given to the Rhizobium accessions in the microbiology laboratory (Date and Halliday 1979; Strickland et al. 1980; Date 1982).

Herbarium Specimens

A well-managed collection and screening system will have herbarium specimens of all accessions so that there is some record of the plants' growth form, to check if the original genotype is what is being grown, for genetic variation studies within species and genera, and to help determine if outcrossing is occurring.

Although each plant collected could be pressed during collection in the field this is an unnecessary burden on the collector. Such specimens may be in very poor shape, not flowering or modified by drought, grazing, etc. Thus, on collection trips just specimens of unknown species normally are pressed. The collected genotypes can have herbarium specimens taken from multiplication plots where more uniform conditions prevail and where samples that are flowering and seeding can be readily obtained.

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APPENDIX 1: TRIP EQUIPMENT

A vehicle appropriate to the roads to be encountered should be taken. If spare parts are not available along the route, spares should be taken following the advice of a mechanic who knows the vehicle. Spare tires, extra petrol, patching kits, tire pump, shovel, machete, pick, and a tow rope are among essential equipment for remote areas.

Personal equipment should include changes of clothing; sunglasses (as glare can bother the eyes when searching for legumes and legume seed); a large hat; an umbrella (one can collect and make records in the rain); medicine; particularly for headache, common cold, and diarrhoea; and a medical kit, which should include tweezers for removing thorns, insect repellent, mosquito net, mosquito coils, insecticide for bed bugs, water container.

Basic Collecting Equipment

Data: collection sheets and clip board, or collection book.

Planning: road maps with important environmental boundaries marked on, or photocopies of environmental maps, topographic maps, altimeter if available, metal tape measure, and compass.

Soil samples: soil auger, pH kit, plastic bags for soil samples, waterproof labeler for soil samples (pencil or indelible pen), and waterproof labels for inside and outside of soil sample bags.

Seed samples: rubber-sided threshing boards; envelopes for seed samples, good quality; stapler to close envelopes, plenty of staples, staple remover; larger paper bags to contain bulky seeds and to organize envelopes; herbarium press, plenty of newspaper, cardboard sheets cut to size, jewelers tags to label plants; notebook or diary; camera and film; rubber bands; plant presses (2); insecticide (household spray with some residual properties); fungicide.

Vegetative material: sturdy shovel, pick, trowel, plastic bags, water container, shears, pruning saw (for browse), adhesive tape for closing plastic bags, box or bag for storage (Walley and Brown 1973).

Rhizobia: shovel, pick, hand trowel, sealable vials, vials with cotton wool and silica gel or $CaCl_2$, scissors, tweezers, container for vials.

Browse: tree secateurs.

Hearts and minds: small gifts for those helping out.

APPENDIX 2: DAILY ROUTINE

Breakfast early, or as soon as restaurant opens; purchase lunch if there will be none available en route; purchase soft drinks and/or replenish drinking water. In hot weather one is sipping all day.

Record the odometer reading of the vehicle to the nearest 10th km, if possible, at a fixed point in the town, e.g., main intersection, town hall, etc. Continue to do this at each town during the day to keep the site location accurate. Also at each new road, record the odometer reading at the beginning.

Calculate the number of stops possible during the working day. About 13 stops is maximum for a day. Plan the day's stops on the map recording the odometer reading for the chosen sites.

At each collection stop, the odometer reading should be recorded, and the vegetation and site should be described. What legumes and grasses are present should be recorded whether seed is present or not. This will allow future collections to be made at the site.

Stop collecting when tired, it is important not to exhaust oneself to avoid illness that can ruin the trip. The last collection should be about 16:00 or 16:30 hours depending on the time started, distance yet to be traveled, condition of the road, and energy of the collectors.

Either before or after dinner, the plant presses should be opened and the newspaper changed if wet;

notes on the day written up; accession sheets reread, made more legible and more detailed; the day's collection of seed cleaned, insects and damaged and diseased seed removed, and insecticide and fungicide added. The next day's travel and collecting stops planned in the light of experience to date; check that the collected vegetative material is in good shape.

APPENDIX 3: ILCA ACCESSION/COLLECTION SHEETS

There are two ILCA detailed Accession/Collection sheets and one general accession form. The two Accession/Collection sheets together provide the information that has been selected as being valuable and likely to be available either at the site of accession or in references elsewhere.

Accession sheets may be of two sorts, those with few general questions and large spaces for answers, or those with many specific questions and small spaces for answers. As computer data organization is based on many specific questions, these sheets have many specific questions to be answered. This means the transfer of data from the collection sheet to the computer does not require the collector to interpret the notes, and data may be entered by a typist. It also means that information that might have been forgotten or overlooked is included.

All questions will not be answerable at a given site or be pertinent. However, if the answer is no or none, it should be written as such. Descriptors without answers are not used in the description of the accession. Collectors should do their best when filling in the sheets at the site of collection to remember that the more information that is included, the more likely that the accession will be useful.

The forms are organized to follow the sequence of input into the computer and to provide a logical sequence of questions in the field.

Sheet I has 3 parts:

(a) General site data -- this section is filled in only once for each general site of collection.

(b) Data from references -- is completed in the office or laboratory after collection.

(c) Field data -- on the reverse of Sheet I, this is completed using a separate sheet for each accession.

The sheets from one site may be fastened to the sheet that has the General Site Data section completed.

Sheet II is filled out in the office or laboratory after collection is completed. It is fastened to Sheet I. It is also used as the only accession sheet for commercial lines of germ plasm for which little or no data are available.

ILCA Accession/Collection Sheet Definitions

Sheet I Species: scientific name (genus and species).

ILCA: The ILCA accession number -- leave this blank (or forms may be prenumbered).

A. General Site Data

Fill this section out in the field once only for each collection site. A site may have many accessions. Section C, Field Data, is filled out for each accession on separate sheets.

Collection site no: Sites for each mission are numbered by the collector consecutively, beginning with number 1. All accession sheets for one site are stapled together.

Collection date: Day, month, year, (as numbers) e.g., 10/12/1984.

Collector's accession numbers at site: Accession numbers assigned by the collector at the site, copied from Section C, Field Data. The numbers of all accessions collected at this site are to be recorded here.

Collectors: The initials and name of each member of the collecting team are recorded here in the same order each time.

Collection institute: The name of the institute(s) with which the collection is associated.

Country collected: The country in which the sample is collected.

State, district, and area: To be obtained from a political map.

Altitude: If an altimeter or a topographic map is used in the field, this may be filled in in this section. Altitude may also be completed in the office and, thus, there is a space in Section B, Data from References.

Exact site: An exact description of the location. The more detailed the description, the better, e.g., along Addis Ababa - Debre Berhan road 20 km (or 20.3 km if possible) from the Shola dairy at the E edge of Addis Ababa. At about 200 m past a small bridge where 2 houses are 50 m E of road, the site is 10 m E of road edge, at the W edge of a Eucalyptus grove.

General site comments: Further details of the general site may be added here if desired, for example, a general description.

B. Data From References

This section is filled out on return to the office after collecting.

Map: reference: From a topographic map of a scale of 1:250,000 or smaller if possible (i.e., 1:100,000). Information given should include map series number, sheet number, edition, and map grid reference, i.e., Ethiopia series EMA 3, sheet NC 37-10, ed. 2, 37B PA 2662, or more accurately 37B PA 265623.

. Latitude - From the topographic map in degrees (°), and minutes (') (60 minutes to 1 degree). Circle whether north or south.

. Longitude - From the topographic map in degrees (°), and minutes ('). Circle whether east or west.

. Altitude - From an altimeter reading that would have been recorded in Section A, General Site Data, in the field, or from a topographic map. If they differ the topographic map should have preference.

Ecological zone: From an ecological map give the general zone, i.e., Guinea savanna, and any specific descriptors, i.e., southern.

Rainfall: Annual in millimeters. Obtain from the nearest and most applicable station. If stations lie on either side of the site, and rainfall changes regularly between them, then the rainfall of the site can be estimated, i.e., collection point A lies 2/3 of the distance between town B with 1,200 mm rainfall and town C with 900 mm rainfall, and closer to town C. If the topography is fairly uniform and rainfall is assumed to diminish regularly between towns B and C, rainfall at point A will be 1,000 mm.

. Seasonality - Give the months in which rainfall occurs. The rainy season(s), for example, in a bimodal rainfall could be (a) January-March, (b) July-September.

. Length - The total number of months in which Lsignificant rainfall occurs. The number of months in the rainy season(s).

Temperature: There are several important temperature parameters that may be available for a site. The growing season temperatures are, of course, more relevant than mean annual temperatures. However, to allow greater utilization of the data, as many of these variables as available should be recorded.

. Mean - The mean annual temperature in degrees Celcius, calculated as for rainfall.

. Average maximum - The average maximum temperature in degrees Celcius.

. Average minimum - The average minimum temperature in degrees Celcius.

. GS mean - The mean temperature during the growing season in degrees Celcius.

. GS mean coldest month - The mean temperature

(°C) during the coldest month of the growing season.

. GS mean warmest month - The mean temperature (°C) during the warmest month of the growing season.

. GS mean minimum coldest month - The mean minimum temperature (°C) during the coldest month of the growing season.

. GS mean maximum warmest month - The mean maximum temperature (°C) during the warmest month of the growing season.

. Frosts - Occur with what frequency (0 nil - 5 frequent) and severity (0 nil - 5 very severe).

Soil: Parent rock - Fill in this section from a geological map if this could not be determined in the field (there is a "parent rock," in Section C under Field Data): sandstone, limestone, shale, granite, basalt, gneiss, alluvium, tuff, laval, etc.

. Names - Fill in this section from a soils map if the soil could not be identified in the field and was not recorded under Field Data. Use whatever system is available, i.e., USDA, FAO, etc. If several names are available, list them all. Include a local class, subclass, and phase if available.

. pH - The pH is best done in the laboratory from a soil sample. It may also have been done in the field and recorded under Field Data. State the method used (H_2O, KCl). There is also a space in Section C under Field Data if the pH is determined in the field.

Analysis: Chemical - List the results from soil analyses of at least major nutrients and the analytical methods used.

. Physical - List the results of the soil analyses for the soil fractions; clay, sand, etc.

Rhizobium number: This will be given in the laboratory. It will consist of the plant's accession number with the suffix R, e.g., ILCAR 6259. In the field, the vial with Rhizobium should be given the collector's number of the accession from which it was taken.

Herbarium specimen: The location of a stored pressed specimen and the person who identified it should be recorded here.

C. Field Data

Each accession at a site must have a separate sheet with Field Data recorded. All the accession sheets for each site are then fastened to the sheet that has the General Site Data section completed.

Site number: The same number that was given to the site in the General Site Data section.

Collector's number: The accessions are numbered consecutively. The number will be followed by the initials of the trip leader. Although numbers may start at 1 from each trip, it is perhaps wiser to have only one of each number in existence for a trip leader. He could thus have increasingly larger collection numbers over the years.

Genus, Species, Subspecies, Variety: Complete if known.

Flowering:* Relative number of flowers. As in all headings marked with an asterisk (*) a 0-5 ranking is used. No flowers = 0, to completely flowering or a great many flowers = 5.

Seeding:* As for flowering, i.e., 0 = no seeds, 5 = all flowers mature.

Ripe seed:* Proportion of mature seeds or seed pods. 0 = none, 5 = all seeds present are mature.

Leafy:* Relative leafiness of the plant. 0 = no leaves, 5 = completely covered in leaves, a very leafy plant. Do not compare the plant to the leafiest you have seen of the species, but to a theoretical plant of the same growth type completely covered in leaves.

Height: The height of the plant in cm.

Spread: The plant diameter in cm.

Morphology: Tree, shrub, herb, vine.

Density:* The number of plants at the collecting spot, from one plant = 1, to a dense patch = 5.

Relative abundance:* The relative abundance of the number of plants in the general area, from 0 = no other, to 5 = very common.

Grazed by: Specify what animals: cattle, sheep, camels, deer, voles, etc.

Intensity:* -The degree of grazing from 0 = none, to 5 = very heavily grazed.

Diseases: Name - The common name, or genus and species if known. Fungus or bacterium if only that much is known.

. Parts affected - Leaves, stems, roots, inflorescense.

. Damage (/10) extent - This is an observation of the percentage (recorded out of 10) of the organs affected, e.g., for a leaf disease, an 8 indicates that 80% of the leaves have the disease.

. Intensity - Again this is recorded as a percentage out of 10 and gives the average damage to the affected leaves, e.g., an observation rating of 5 indicates an average of 50% of each affected leaf is damaged. This is useful where the leaves are more or less uniformly affected. If they are not, the ratings could be recorded as a range, e.g., 1-8.

. Description - Describe disease and its effect on the plants.

Pests: Name - The common name, or genus and species, if known, type of pests, e.g., insect, nematode, or other.

. Parts affected - As for diseases.

. Damage (/10) extent - As for diseases.

. Intensity - As for diseases.

. Description - Sucking, boring, chewing, etc. Describe pest and its effect on the plants.

Management: The management of the site of collection. This involves any regular, human-directed treatments of the environment or plant. This may include grazing, irrigation, mowing, etc.

Management detail: Specific detail on above management conditions. Inquire from local residents.

Fire: When was the area last burned over? How often does this occur?

Aspect: The direction of the slope of the land in degrees, e.g., 350°.

Slope: Record in words, or degrees if measured. 0-1° flat or almost flat, 1-3° moderately sloping, 7-14° sloping, 14-29° steep, and greater than 29° very steep.

Topography: Rolling, flat, etc.

Position in landscape: At the bottom of a steep cliff, half-way up a small hill, etc.

Soil: Parent rock - If it is known in the field, sandstone, limestone, shale, granite, basalt, gneiss, alluvium, tuff, lava, etc.

. Name - If you recognize the soil type in the field, vertisol, nitosol, etc. plus the name in any other system you may know.

. Colour - Dark gray, mottled, dark red, light brown, black, etc., or give the code from Munsell's chart.

. pH - If the pH is taken in the field, record it here and the extracting solution, i.e., 5.9, H_2O.

. Texture, sand - Loose and single grained, see or feel individual grains; when dry it falls apart when squeezed in the hand and released; when moist, a cast of squeezed material remains but crumbles when touched.

. Silty-loam - Lumpy (clods) when dry but can be readily broken; feels soft and flourery when pulverized. When wet readily runs together and puddles. Forms cast dry or wet that can be freely handled without breaking but when moistened and squeezed between thumb and finger will not ribbon but gives a broken appearance.

. Clay - Breaks into clods or lumps that are hard when dry. When pinched between thumb and forefinger it forms a thin ribbon that breaks readily, barely sustaining its own weight. Plastic, forms a cast that bears much handling. Kneeded in the hand it does not crumble readily but forms a heavy compact mass.

. Loam - A rather even mixture of sand, silt, and clay. A somewhat gritty feel, fairly smooth, slightly plastic. When squeezed when dry it forms a cast that requires careful handling. Moist casts can be handled freely without breaking.

Drainage, surface: 0 = Ponded - water passes through soil, or evaporates, no runoff.

. 1 = Very slow runoff - free water lies on surface or enters soil immediately, level or porous soil.

. 2 = Slow runoff - water covers soil for significant period or enters soil rapidly, nearly level, gently sloping, little or no erosion when cultivated.

. 3 = Medium runoff - water covers soil for short periods, a moderate proportion enters soil; slight to moderate erosion when cultivated.

. 4 = Rapid runoff - a large proportion of the water moves rapidly over the surface, only a small part goes into the soil, runs off as fast as it is added, low infiltration capacity, moderately steep to steep slope, moderate to high erosion hazard.

. 5 = Very rapid runoff - very little infiltration, water runs off as fast as added, steep to very steep slope, low infiltration capacity. Erosion hazard high to very high.

Drainage, internal: 0 = No free water passes through particularly when water table at the surface.

. 1 = Very slow - too slow for growth of important crops. Saturated for 1-2 months. Blotched or mottled in nearly all parts of the profile, some gray surface soils. May be due to high water table, a very slowly permeable horizon or both.

. 2 = Slow - affects the roots of most plants; saturated with water for 1 or 2 weeks. If slow internal drainage then black or gray A horizon, mottling or blotching in the lower A or upper B, lower B and C. Relatively high permanent or fluctuating water table.

. 3 = Medium - water saturation limited to a few days, less time than required to injure plant roots. Optimum for growth of important crops under humid conditions, most soils free of mottling and blotching through A horizon and all or most of B.

. 4 = Rapid - water saturation only for a few hours. Drainage somewhat too rapid for important crops of humid regions.

. 5 = Very rapid - soil never water saturated, too droughty for important crops of humid regions. Free of mottlings for several feet.

Plants Sampled: No. = Specify the number of plants sampled, 1 (the best sample) or more.

. Material - What material was collected: seed or vegetative.

. Rooting habit - Deep tap root, shallow tap root, deep spreading, shallow spreading, fibrous.

. Nodules collected - Yes/no

. Herbarium specimen - Yes/no

. Photograph - Not taken (record no), or if taken record the number of the photo.

. Local name - The name of the plant used by the people in the area where it was collected.

. Ethnic group/language - The language of the local name, or the name of the ethnic group.

. Habitat - Description of the site in some detail, and the location of the plant within the site.

. Disturbance - Disturbance differs from management in being nonregular and/or not caused by man and may include such treatments as bulldozed area, road margin or ditch, eroded, flooded, logged.

. Vegetation type - Forest, woodland, grassland, desert, etc. If possible record the full scientific name, i.e., Acacia tortilis woodland with Chloris gayana and Hyparrhenia hirta.

. Associated grasses - List the scientific or common names of the grasses found at the collection spot. Indicate which are dominant in the habitat.

. Legumes: As for grasses.

. Others: Herbs, shrubs, trees, etc., as for grasses.

. Comments: Any other information that you feel would be of use in interpreting the adaptability of the plant, i.e., an assessment of general vigour or potential.

Sheet II

This sheet is filled out in the office or laboratory for each collected accession and fastened to Sheet I. Acquired accessions, such as commercial lines may have only this information available. Thus, just Sheet II is required without Sheet I. Most of the definitions are either obvious or given on the sheet.

Growth zone: This descriptor is used to simplify catalogue preparation. As it is very difficult to classify accessions according to growth zones, species, and genera that are mainly in, or dominate in, a given environment are grouped there, no matter where collected. This avoids arbitrary delineations between temperate and subtropical, and the same species appearing in several groupings in a catalogue. More precise groupings can be obtained by grouping on altitude and temperature.

Plant type: This descriptor is again used to simplify catalogue preparation. Again the division of genera or species into browse or legume is arbitrary, however, as some system must be followed, perhaps the simplest is to classify all members of a given species as browse or herbaceous legume, whether all the members might fit the definition or not. Examples of two general of which members may be considered herbaceous legumes or browse are Aeschynomene and Desmanthus. The main rule should be: be consistent.

Genetic status: These definitions are designed to suit cereal and cultivated crops as well as forage crops.

. Wild - Not cultivated, persists without the intervention of man.

. Weedy - Not cultivated, but required the intervention of man.

. Primitive cultivar/land race - a cultivated crop, not necessarily consciously bred.

. Breeders line - a consciously bred line, advanced cultivar, a selected breeders line, released commercially.

Parentage: The genetic makeup of bred lines.

Other accession numbers: List all other accession numbers known for the line. This will greatly reduce duplication in a collection.

Source: Where did the seed come from originally, if not a collection? Be certain to include the name of the scientist involved. Include other sources from which the seed is received.

ILCA Accession Sheet — General Form

Species: ____________________ Accession no.: ____________

Date: ____________________ Collector: ____________

Site location: ______________________________________
____
____
____
____
____
____

Map reference: ______________________________________
____

Latitude: __________ Altitude: __________ Rainfall: __________ mm

Temperature: ______ °C Morphology: __________ Flowering:* __________

Seeding:* ________ Ripe seed:* __________ No. plants sampled: ________

Leafy:* ______ Height: ______ cm Spread: ______ cm Density:* ______

Relative abundance:* __________ Grazed:* __________ by: __________

Fire: __________ Aspect: __________ ° Slope: __________

Texture: ____________________ Parent rock: ____________

Drainage: (surface) ______ (internal) ______ Ph: ______ Photo: ______

Soil name: ______________________________________

Habitat and disturbance: ______________________________________
____
____
____
____
____
____

Associated species: ______________________________________
____
____
____

Remarks: ______________________________________
____
____
____
____
____

* Ranked 0 to 5.

ILCA Collection/Accession Sheet I

Species: ____________________ ILCA no. ____________________

A. GENERAL SITE DATA

Collection site no. ____________________ Collection date ___/___/___

Collection accession numbers at site ____________________

Collectors ____________________

Collecting institute ____________________

Country collected ____________________ State ____________________

District ____________________ Area ____________ Altitude ________

Exact site ____________________

General site comments ____________________

B. DATA FROM REFERENCES

Map: reference ____________________

latitude _____ ° _____ ' N/S, longitude _____ ° _____ 'E/W, altitude _____

Ecological zone: general ____________________, specific ____________

Rainfall: annual _____ mm, seasonality (mo) (a) ____________________

length ____________________ mo. (b) ____________________

Temperature: mean _____ °C, average maximum _____ °C, average minimum _____ °C

growing season (GS) mean _______ °C GS mean coldest mo. _______

GS mean warmest mo. __________ °C GS mean min. coldest mo. _____

GS mean max. warmest mo. _______ °C frost: frequency* ____________

Soil: parent rock ____________________ name(s) ____________________

____________________ pH ____________

Analysis: chemical ____________________

physical ____________________

Rhizobium: number ____________________

Herbarium: specimen stored where ____________________

identified by ____________________

* Observed on a scale of 0 (least) to 5 (most).

C. FIELD DATA

Site no. ______________________ Collector's no.______________

Genus______________________ Species______________

Subspecies ______________________ Variety______________

Flowering*___ Seeding*___ Ripe seed*___ Leafy*___ Height __cm Spread __cm

Morphology ____________ Density*________ Rel. abundance*______

Grazed by ______________________ Intensity*______________

Diseases: name______________ parts affected______________

damage (/10) extent______________________ intensity__________

description____

Pests: name______________ parts affected______________

damage (/10) extent______________________ intensity__________

description____

Management____

Management detail____

____

Fire______________ Aspect__________° Slope______________

Topography____

Position in landscape______________________________________

Soil: parent rock______________ name(s)______________

______________ colour__________ pH______ in______

texture______________ drainage: surface________ internal*______

Plants sampled: no.______________ material______________

Rooting habit__________ Nodules collected______ Herbarium specimen______

Photograph______ Local name______________ Ethnic group/lang.__________

Habitat: ____

____

____

Disturbance____

Vegetation type____

Associated: Grasses______________________________________

____

Legumes____

Others____

Comments: ____

____

____

____

____

____

* Observed on a scale of 0 (least) to 5 (most)

ILCA ACCESSION SHEET II

(To be attached to Collection Sheet I, or alone for accessions with no data on site of origin.)

Species:____________________ ILCA no.:________

Subspecies:____________________ Authorities:________

Variety:____________________

Convariety:____________________

Cultivar:____________________ Acc. date___/___/___ d m y

	Genus	Species	Sub sp.	Variety	Authority
Synonyms 1					
2					
3					
4					

Longevity: annual/biannual/perennial

Growth zone: temperate/Mediterranean/tropical/subtropical/highland tropical

Plant type: herbaceous/legume/grass/browse/cereal/other

Genetic status: wild, weedy, primitive cultivar/landrace, breeders line, advanced cultivar

Parentage:____________________

Crop name:____________________

Other acc. nos.:____________________

Source: name____________________

organization____________________

address____________________

other sources____________________

Comments:____________________

GERM-PLASM STORAGE AND DISSEMINATION

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Abstract *An exemplary work procedure for orthodox seeds is given describing the handling of germ plasm entering a genebank until final storage under long-term conditions, i.e., at low-seed moisture content, subzero temperatures, and hermetically sealed in airtight containers.*

To enhance dissemination and utilization of germ-plasm description of the collection site, the morphological and agronomical characters as well as specific traits such as tolerance to abiotic or biotic stress are indispensible prerequisites. Only with this information can germ plasm be accurately channeled into breeding programs.

Because of the high cost of collecting, maintaining, describing, and conserving germ plasm, regional gene-banks are required to serve a large area that spans political borders and necessitates the unrestricted global exchange of material and information.

The strategy of a genebank to conserve germ plasm is determined by the type of propagation of its mandate crops. Asexual propagated plant species such as banana are maintained in living collections, either in nurseries or arborata, or as meristeme culture as it is introduced in potatoes, for example. In sexually propagated plant species, the seeds are categorized according to their storage physiology into "orthodox seeds" and "recalcitrant seeds." The first group comprises most of the agricultural plants including forage and pasture crops. Recalcitrant seeds belong mainly to tropical fruit trees such as mango, avocado, cacao, or coconut, and forest trees like oak or chestnut. Orthodox seeds can be dehydrated without being damaged, but, in contrast, the viability of recalcitrant seeds depends on a relative high-water content. However, dehydration is one of the prerequisites to extend the longevity of seeds, in particular when stored at subzero temperatures, otherwise freezing water in the seed tissue leads to lethal injuries. Therefore, germplasm of plant species with recalcitrant seeds are also maintained in living collections.

The type of conservation, as a living collection or as seeds, also determines the dissemination of germ plasm. In living collections, the prospective user can compare and select the appropriate germ plasm from a permanent display of the material, however, a genebank conserving seeds can offer only either a one-season display of a portion of the whole collection (during multiplication) or usually only seed samples with the description of the corresponding plant. In the latter, the user has to rely on the accuracy and comprehensiveness of the information when requesting germ plasm. In the paper, the conservation and dissemination of germ plasm from plants with "orthodox seeds" will be discussed using the Plant Genetic Resources Center of Ethiopia (PGRC/E) as an example.

SEED CONSERVATION

The reduction of the seed moisture content (SMC) extends the longevity of orthodox seeds. Harrington's (1963) "rule of thumb" expects a doubling of longevity if the SMC is reduced by 1%. Therefore, seeds with 4% SMC are expected to retain viability approximately 1,000 times longer than seeds with 14% SMC.

A second determining factor for extending the life expectancy of seeds is temperature. Another "rule of thumb" indicates that longevity of seeds is also doubled by reducing the storage temperature by 5 °C (within a range of 50 to 0 °C). Because both factors, moisture content (MC) and temperature, are obviously acting independently (Harrington 1970), seeds with an SMC of

4% and stored at 0 °C have a 1,000 x 10^3 times longer life expectancy than stored with 14% SMC at 50 °C.

Apart from the relative rough estimation of the storage life time of seeds with Harrington's rules of thumb, many attempts have been made to predict more precisely the storage duration of seeds. In this respect Roberts and Abdalla (1968) have developed crop-specifically advanced equations and nomographs to calculate and determine the survival probability of a certain seed lot (Ellis and Roberts 1980).

Knowledge of the rate of ageing during storage is indispensible to determine the interval of rejuvenation of the stored seeds. According to the negative correlation between storage temperature/SMC and longevity, the lower the temperature (and SMC) the longer the rejuvenation interval. As shown by Roberts (1975) wheat stored at +4 °C with 9% MC has to be stored up 9 years, whereas wheat stored at -20 °C and 5% SMC can be stored for 390 years. Corresponding figures for Hordeum distichum are 109 and 33,500 years and for horsebean 20 and 1,600 years, respectively.

Apart from the interaction between storage conditions and longevity the time interval for rejuvenation is also dictated by the initial viability of the seeds. According to Ellis et al. (1980), barley stored at -18 °C with an initial viability of 100% requires rejuvenation only after 8,050 years; with 95% viability, 1,560 years; and with only 90% initial viability, 620 years. In this context, the environmental conditions before harvest can influence considerably the viability (Austin 1972), which in turn will also have an influence on the rejuvenation interval.

A third factor determining the storage durability of seeds is the oxygen pressure (Roberts and Abdalla 1968). Oxygen enhances respiration, which reduces seed viability, and it is noteworthy that with sealing as it is normally done oxygen pressure is reduced.

When considering the storage lifetime of seeds, not only the change of the viability in the course of time should be kept in mind but also changes in the genetic integrity (Abdalla and Roberts 1968).

Based on the experience of other genebanks, the recommendations of IBPGR and the specific conditions of the host country PGRC/E has developed the following procedure for long-term storage of orthodox seeds. (Fig. 1).

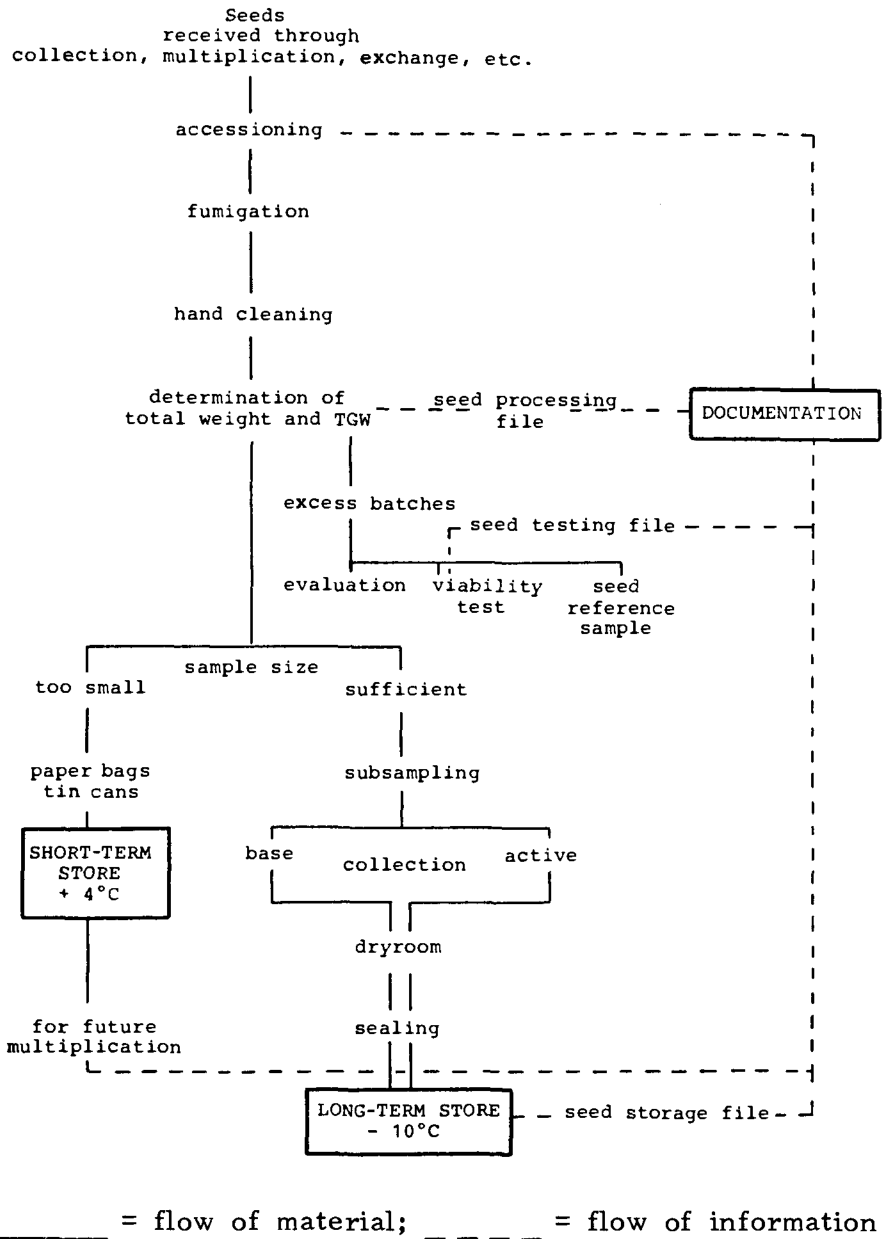


Fig. 1. Scheme of seed processing for long-term storage at PGRC/E.

(a) Accessioning of the Samples. All samples entering the genebank, either through collection or seed exchange, receive an accession number before further handling. The accession numbers are assigned consecutively regardless of the crop type. It is questionable whether a crop index number or letter should be added to the accession number to assist crop identification, especially when a genebank deals with many different crop types.

(b) Fumigation. As a phytosanitary measure, all seed samples coming from the field are fumigated for 72 hours with Phosphin to control further damage of the seeds and to avoid infestation of the genebank with insects carried by the samples.

(c) Hand Cleaning. Because of the enormous heterogenity of Ethiopian germ plasm, the threshed samples are hand cleaned to avoid mechanical selection according to the seed size. The efficiency of handcleaning declines with the seed size. In cereals, to clean 200-250 samples a week, 6-8 workers are necessary. At the same time, cleaning samples composed of different crop types are separated into "one-crop samples."

(d) Determination of Sample and Thousand-Grain Weight. Thousand-grain weight (TWG) is one of the characteristics describing an accession. Together with the total sample weight, TGW is also necessary to determine the sample size based on the seed number. At PGRC/E, the standard sample size for long-term storage is 8,000 seeds in heterogeneous material and 3,200 seeds in genetically uniform (homogeneous) samples. The standard sample size applies to crops with a TGW of 5-200 g. For practical and economical reasons, in large-seeded crops (TGW above 200 g), such as horsebean or maize, the corresponding sample sizes are 4,000 and 1,600 seeds, and in small seeded crops with a TGW below 5 g, such as millet or teff, one takes samples weighing 80 and 32 g, respectively. TGW is determined by taking two samples of 500 seeds each, weighing them, and calculating the mean weight. One batch of the seeds used is kept apart for the consecutive viability test, provided the sample size fulfills the above mentioned standard requirements. The second 500 seed batch used is kept as a seed reference sample.

As seen in Fig. 1, samples smaller than the required limit are stored in paper bags or tin cans under short-term conditions (+4 °C and 35-40% relative humidity (RH)). Large samples exceeding the limit are adjusted to the indicated standard sizes, the excess material is used for immediate further evaluation.

At PGRC/E, sample size and TGW are determined by a two-person team equipped with an electrical balance, an electrical seed counter and a calculator. The data are recorded manually in a crop-specific "seed-processing file." The data are then transferred after compilation into the computerized documentation system. The handling capacity is approximately 200-250 samples/week.

(e) Viability Test. The test procedures strictly follow rules developed by the International Seed Testing Association (ISTA) (1976) for both the number of seeds per replicate and the time interval for the first and second counting. The results are also recorded manually using a "seed testing file" and after compilation they are transferred to the documentation unit. For the viability test, PGRC/E is equipped with the standard tools such as a water deionizer, autoclave, germination room (20 °C), and an incubator for alternating temperatures. During viability testing, care must be taken not to mix up dormancy with low viability.

(f) Subsampling for Long-Term Storage. Heterogeneous standard samples (8,000 seeds) are subdivided into 3,000 seeds for "base" and 5,000 seeds for "active collection." The latter is subsampled into five equal portions. Homogeneous material (e.g., ear-to-row progenies) is equally subsampled in eight batches of 400 seeds, one subsample is kept in the base and the remaining seven subsamples in the active collection. The corresponding quantities for small-seeded crops are 30 g for base and five samples of 10 g each for the active collection in heterogeneous accessions and eight samples of 4 grams each in uniform material, and in large-seeded crops half of the quantity of a standard sample is used.

All samples, the base and the active collection are stored at the same temperature (at present -10 °C, in future -20 °C) but in separate coldrooms. The base collection is used for undisturbed long-term conservation, the active collection serves for seed exchange, monitoring the viability, research, breeding stock, etc. The quantities shown differ in some respect from the recommendation given by IBPGR (Cromarty et al. 1982). According to IBPGR a genebank should conserve not less than 12,000, 3,000, and 5,000 seeds for base, duplicate, and active collection in heterogeneous accessions, and 4,000, 1,000 and 3,000 seeds in genetically uniform material, respectively. Furthermore, only the base collection (and the duplicate samples) are stored under long-term conditions but not the active collection.

The lower quantities adopted by PGRC/E are based on PGRC's collection strategy that states that in areas with a high degree of diversity instead of collecting one or few large samples more smaller samples should be taken. This also takes the relative small plot sizes of the Ethiopian farmer's field into account. By that, a sample composed of, e.g., 20-30 spikes of self-pollinating crop might, after multiplication, be very well represented by a 1,000 seed subsample. The deposition of a safety duplicate from each of the accessions (active collection) in one of the corresponding genebanks outside of Ethiopia is under operation.

As indicated, the active collection is stored as individually sealed subsamples and not as a bulked large sample. With this procedure, unnecessary exposure of the whole sample to the atmosphere outside of the coldroom and, therefore, the possible absorption of moisture is avoided if a subsample is taken. As is already known, bodies colder than the dewpoint temperature of the ambient atmosphere will condense water from the air. To illustrate the fact, at +25 °C air temperature and 80, 60, or 40% relative humidity the corresponding dewpoint temperatures are +21, 17, and 11° C, respectively. This means, seeds taken from a -10 °C coldroom and exposed immediately to the outside atmosphere will, because it is colder, definitely condense and absorb moisture unless the seed temperature is in equilibrium with the air temperature first before the container is opened.

(g) Drying of Seeds. To reduce the seed MC before sealing and storing, the samples are placed in a dryroom operating at 10-15% RH at 20 °C. In the dryroom, the equilibrium seed MC at a given temperature depends on the RH of the ambient air and the oil content of the seeds as shown in Table 1.

Because of the hydrophobic nature of lipids, the higher the oil content the lower is the equilibrium seed MC. The figures reveal, furthermore, that to reach, e.g., in wheat or barley seeds, an MC of at least 6% (dry base) the RH in the dryroom has to be at least 15%. Because of the interdependency between air temperature and RH, increasing the dryroom temperature would also lower the equilibrium seed MC. However, care must be taken not to overheat the seeds.

The time requirement to reduce the seed MC is determined, in addition to the parameters already mentioned, by the difference between initial and final SMC, the wind velocity in the dryroom, and the seed size. Millet seeds, for instance, with an oil content similar to sorghum but with a 10 times smaller TGW (2 compared to 26 g in sorghum), would need only 3 hours to

Table 1. Equilibrium MC of seeds that differ in oil content as affected by the humidity of the atmosphere at 25°C.[a]

Crop type	Oil content (% DM)[b]	Seed MC (% DM)	
		20% RH	15% RH
Horsebean, field pea, lentil	1.5-1.9	7.1	6.0
Barley, wheat	1.7-1.9	7.1	6.0
Maize	4-5	6.9	5.9
Sunflower	32	4.8	4.1
Rapeseed	45	3.9	3.4

[a] Source: Data derived from equation 3.5 (Cromarty et al. 1982).

[b] DM = dry matter, MC = moisture content, RH = relative humidity (air temperature 25°C).

reduce the MC from 10 to 6%; sorghum, in contrast, requires 16 hours under the same dryroom conditions (25 °C, 15% RH, and 1 m/s wind speed).

Although the figures in Table 1 provide valuable basic information, the frequent determination of the actual MC of the seeds during the drying process remains as a necessary measurement to safeguard the germ plasm. To determine SMC, two methods can be employed, either gravimetrically or by following the weight loss of reference samples in the course of exposure time. In the latter the final weight is given by the equation:

$$W_f = W_o(100 - M_o)/(100 - M_f)$$

where W_o, and W_f, M_o, and M_f are the initial and final weight and moisture content, respectively (Cromarty et al. 1982). If the gravimetrical method is used, ISTA rules should be followed.

(h) Sealing of the Samples. At PGRC/E, the samples are sealed in laminated aluminium foil bags, heavy quality of approximately 110 g/m^2. Alternatives are the storage in air- and moisture-tight plastic bottles (e.g., at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)), glass jars (Gatersleben), or corrosion- and leakage-proof tin cans (Izmir). To monitor leakages the International Rice Research Institute (IRRI) is using evacuated aluminium cans for long-term storage.

(i) Coldroom. The coldrooms at PGRC/E are equipped with mobile shelves, subdivided into compartments. i.e, the intersections of the vertical shelf column with the horizontal rack. For identification of the position of an accession, the shelf compartments are labeled with four-digit numbers indicating sequentially the number of the coldroom, shelf, column, and rack. For recording the position and stock control, the "storage file" is used.

For long-term storage the coldroom operates at -10 °C without humidity control, and for short-term storage at +4 °C and 35-40% RH. Power supply is provided by two independent electrical power lines; an additional stand-by generator will be fixed soon.

To economize the available coldroom space and to reduce running costs, the more expensive mobile shelves should be given preference over the cheaper static shelves. Taking PGRC's new 100 m^3 long-term storage into consideration, with a floor area of 37 m^2 the eight mobile and two static shelves provide a shelf area of 248 m^2. If the same coldroom is equipped only with static shelves, the same floor area would provide only 140 m^2 of shelf area, i.e., 57% of that of the mobile shelves. In other terms, providing the same shelf area with static shelves, the floor area of the coldroom has to be increased to 66 m^2 leading to a total coldroom volume of 177 m^3. Due to enlarging the coldroom volume and, therefore, extending the coldroom surface, not only the initial costs would be increased but also the annual power costs. The annual power costs for a 100 m^3 coldroom as installed at PGRC/E can be estimated by US$750, if enlarged to 177 m^3, US$1,200 (calculations based on formulas given by Cromarty et al 1982). The initial cost for a 100 m^3 coldroom including mobile shelves can be calculated at about US$60,000 (FOB), increasing the volume to 177 m^3 would increase the initial costs by 50-70%.

The storage capacity of the coldroom as described above (100 m^3 volume and 248 m^2 shelf area) is approximately 80,000 standard samples of base collection (e.g., barley, 3,000 seeds sealed in Al-foil bag) or approximately 36,000 accessions as active collection with five subsamples (1,000 seeds) each. At PGRC/E, the samples in the Al-foil bags are kept together in cartons of two different sizes (30 x 24 x 8 cm and 30 x 12 x 8 cm) storing either 25 (12) samples of base collection or 11 (6) accession as active collection (in brackets the capacity of the smaller carton). In each compartment (90 x 60 cm) six large and two small cartons can be placed. Each carton is labeled with the compartment number and -- compartmentwise -- with a carton serial number.

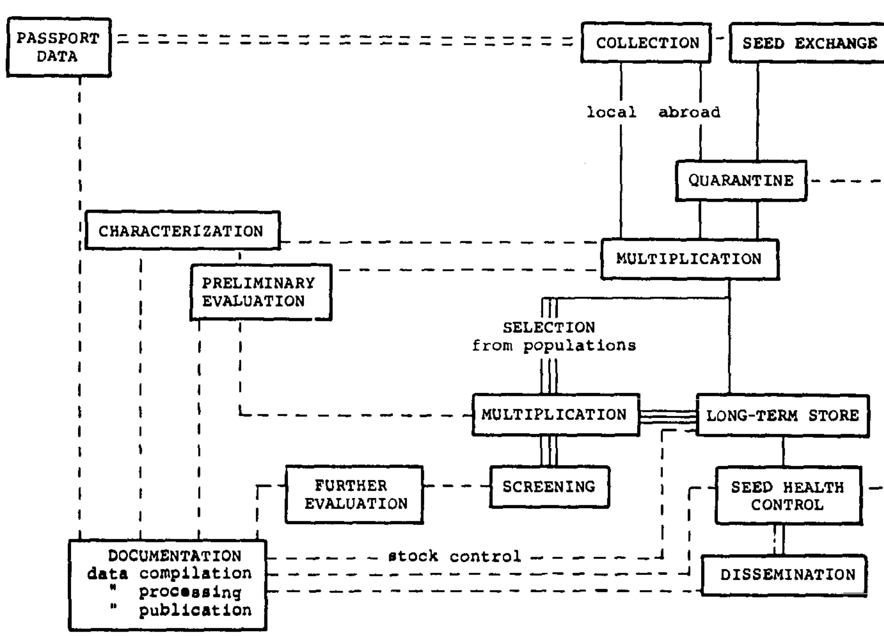
DISSEMINATION OF GERM PLASM

It is forseable that a genebank failing to disseminate germ plasm would be degraded and considered merely as a "seed museum." It is also true that plant breeders often hesitate to introduce germ plasm into their breeding programs due to the possibility of losing the already high levels, e.g., in yield or resistance, if less known material is crossed in.

To overcome the hesitation of the plant breeder and, therefore, to enhance dissemination and utilization of germ plasm, two approaches should be discussed (a) to increase the information about appearance and properties of the germ plasm and (b) to involve the plant breeder directly in genebank activities.

To describe germ plasm comprehensively, three sets of data are used in principle, (a) the passport data, (b) data from characterization, and (c) results from evaluation (Fig. 2).

At PGRC/E, passport data consist of up to 21 single pieces of information describing the geographic location and the ecological situation of the collection site, for example, longitude, latitude, soil character-



______ = flow of material; _ _ _ _ = flow of information

Fig. 2. Scheme of data compilation during increase of germ plasm at PGRC/E.

istics, topography, etc. With this base information, accessions can be earmarked for desirable characteristics, e.g., tolerant to extreme soil reactions or water regimes, according to the environmental conditions of the collection site.

Characterization describes mainly highly heritable morphological characters such as spike density, glume colour, or kernal colour. The information gathered during characterization assists in creating an image of a certain genotype. The accuracy, however, depends on the degree of heterogenity of the accession, the more uniform the material the more accurate the description.

Evaluation can be subdivided into "preliminary" and "further" evaluation. The first describes mostly less-heritable characters, such as days to flower, plant height, number of tillers, or TGW. Although those results are based usually on only one season, one location, without replicates, the information helps to narrow the number of genotypes suitable for a certain breeding program. Like characterization, the reliability of the data is also determined by the degree of heterogenity of the accessions.

Characterization and preliminary evaluation are usually combined in descriptor lists. Common for both is that collection and recording of the data are normally done during multiplication as indicated in Fig. 2.

Further evaluation considers mainly specific traits, such as quantity and quality of yield components or constituents, or tolerance to abiotic and/or biotic stress. This demands a relatively high input of sophisticated methods and equipment, the necessity of specialized personnel as well as highly homogenous germ plasm to yield reliable and reproducible results. To achieve the latter request, subsamples of the original population as collected should be split into single lines even to the expense of invading the genebank with large numbers of single lines. However, before procuring sophisticated and expensive equipment and employing specially trained personnel a genebank should compare whether further evaluation of germ plasm would be done better in well-equipped and experienced institutions outside of the genebank or sending the material to areas that have certain abiotic or biotic stress situations (hot spots).

To assist the potential user in selecting the appropriate germ plasm, local varieties or standards should be included in the characterization and evaluation program. At the same time, the genebank can estimate the potential of the conserved germ plasm if compared with known standards as shown in the following few examples.

In a field experiment, conducted in 1982 at Kulumsa/Ethiopia, 61 accessions of PGRC's breadwheat collection (BW) and 142 accessions of the durumwheat collection (DW) have been compared with three widely used standard varieties in Ethiopia; Romany BC, Enkoy (BW), and Cocorit (DW). The results revealed that none of the breadwheat accessions but nearly 33% of the durumwheat accessions significantly outyielded the standards. Consequently, if an Ethiopian plant breeder is looking for yield increases in wheat, the breadwheat collection of PGRC/E might not be as promising as the durumwheat collection.

In a second example, the protein content in seeds of 222 accessions of Ethiopian sorghum germ plasm was compared with that of four local lines (Table 2). Astonishingly, more than 33% of the tested accessions (single lines) had a seed protein content higher than

Table 2. Comparison of the protein content in the dry matter of seeds of 222 Ethiopian sorghum accessions with four local varieties (protein = N x 6.25).

	Protein %
Germ plasm	
Mean	10.5
Range	5.1-15.3
Varieties	
Didessa	8.1
Melakmesh	9.3
Bakomesh	10.6
Gambella	10.9

the standard varieties. It can be expected that with testing all of PGRC's nearly 7,000 sorghum accessions, the number of high-protein genotypes will be high.

With a simple soil test, 654 wheat lines selected from populations have been tested for tolerance to acid soil. Nearly 9% of the tested material appeared to behave similarly to the known tolerant varieties of Chinese Spring, Vila Velha, and Trintani. Although breeding for tolerance to soil acidity in Ethiopia is only a minor priority, the results might be interesting for other countries suffering from soil acidity, and it might also be relevant to the land-use plan for Ethiopia. It is understood that other crop types such as pasture and forage crops may demand screening of different traits.

A second step to overcome the hesitation of plant breeders to use even primitive germ plasm is to involve plant breeders directly in the different aspects and activities of the genebank. Thus, with the permanent contact with germ plasm, the plant breeders may loose their suspicions and accept germ plasm. In this respect, an ideal combination is, of course, setting up the genebank under the same roof with plant breeding as at ICRISAT. In Ethiopia, although PGRC/E is located separately from plant breeding stations, PGRC/E is incorporated into the national breeding program in activities such as multiplication/rejuvenation being done within the plant breeding stations. Through this arrangement the Ethiopian plant breeders are automatically involved in those activities, and they also have the unique opportunities (a) to earmark promising genotypes, (b) to influence the development of descriptor lists, and (c) to encourage the genebank to look for specific traits the breeders are interested in. In this context, the cooperation between genebank and breeder is already in existence in planning and collection missions.

Irrespective of the method of improving dissemination before despatching germ plasm, the genebank has to perform appropriate seed health control measurements. The control of seed health is, however, not only restricted to checking outgoing material (as indicated in Fig. 2), but it also includes phytosanitary and plant protection measures during multiplication and processing of the seeds as well as plant quarantine for material coming from abroad.

CONCLUSION

Dissemination and utilization of germ plasm depend on appropriate maintenance of the material and the accuracy and comprehensiveness of the description and evaluation. The extent of dissemination will increase by strengthening the involvement of plant breeders in the activities of the genebank. However, both conservation as well as characterization and evaluation are connected with relatively high costs (a) to install, run, and maintain the technical setup; (b) to maintain the labour-intensive fieldwork; and (c) to finance characterization and evaluation. It is still an open question whether the costs should rest exclusively on the host country, to be covered by international funds, or through licensing the germ plasm to determine continued, undisturbed long-term operation of the genebank. Considering the high operational cost, a genebank, regardless of its mandate crops, should not restrict its activity to the national level but should serve regional areas as the mandates for the international agricultural research centres such as ICRISAT or ILCA cover. It is also necessary to ensure the unrestricted global exchange of seeds and information to spread the dissemination and utilization of germ plasm.

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TROPICAL PASTURE GERM-PLASM EVALUATION: STRATEGY AND EXPERIMENTAL DESIGNS

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Abstract *Most large-scale pasture development programs involve the evaluation of a wide range of pasture germ-plasm material. The source of the material may be the country for which improved pastures are intended, other countries with a similar climate, or both. In tropical Africa, where pastures comprise mainly unimproved natural grasslands and the potential performance of indigenous pasture plant species in different environments has not been thoroughly investigated, the case for germ-plasm evaluation seems stronger than in the temperate and other tropical regions. This paper outlines the strategy and methodologies recommended for the evaluation of pasture germ plasm in the tropics, with particular emphasis on the planning of an evaluation program and experimental procedures and designs. Reference is made to proven methodologies in temperate regions where considered appropriate.*

PLANNING A PASTURE GERM-PLASM EVALUATION PROGRAM

A germ-plasm evaluation program basically comprises a series of experiments that are conducted to provide information leading to the selection of suitable material and/or a package of suitable management practices for the country (or part of a country) in which improved pastures are to be developed. When the decision to undertake pasture germ-plasm evaluation has been made it becomes necessary to plan the program, showing clearly the objectives; the criteria for evaluation; the various experiments and methods to be used; the financial, material, and personnel requirements; and a time-table of the activities envisaged. The more important of these components of the program are discussed in the following section.

Definition of Objectives

A clear definition of objectives, indicating the problems to be studied and their relevance to the animal industry, is the first step in planning an evaluation program. If the objectives cannot be defined, there is little chance of them ever being achieved. The first consideration in defining the objectives is to identify what lands (i.e., regions) offer most promise in terms of pasture and livestock development. This requires a knowledge of alternative forms of land use and other factors (sociological or political) that may favour particular regions for pasture development.

The second consideration is to determine environmental limitations to pasture and livestock development. This requires a knowledge of the climate, soils, existing vegetation, and the current land use in the regions identified for pasture development. Where the grazing industry already exists, bottlenecks in the production system (e.g., overgrazing, low-quality forage, diseases, and pests) should be identified. The third consideration is the general level of pasture development to be attempted; that is, whether pasture development will involve better management of existing pastures, introduction of improved species into existing pastures, or replacement of indigenous species with improved ones.

Another question to be considered is whether the program should concentrate on indigenous germ plasm to identify some adapted promising material (e.g., Akundabweni (1984) at the International Livestock Centre for Ethiopia (ILCA) or should it merely evaluate proven cultivars. In the tropics, concentration on indigenous germ plasm may be justified by the need to assemble, identify, and conserve gene pools of potentially valuable legumes and grasses before they disappear through the expansion of land clearing and cultivation (Hutton and Henzell 1976).

A further consideration in defining the program objectives concerns the social and economic conditions (e.g., land tenure systems, pasture utilization systems, farm sizes, educational level of farmers and their financial resources, and their general level of know-how in the animal industry) prevailing in the regions identified for pasture development. These conditions have to be taken into account if relevant objectives are to be formulated.

Criteria for Evaluating Pasture Germ Plasm

Pasture plant species and varieties are usually judged in terms of their productivity, persistence, feeding value, ease of establishment, and associative ability (Shaw et al. 1976; Williams et al. 1976; Whiteman 1977; Humphreys 1978). The environment of the region for which improved pasture are required and the aims of improved pasture use will decide the relative importance of the various criteria in a germ-plasm evaluation program. It is important, therefore, that suitable criteria are identified and techniques for measuring them determined during the planning of an evaluation program. These aspects will be further referred to later in this paper.

(a) Productivity, in terms of both seasonal and total annual dry matter yield, is an important attribute because superior performance of a species creates a larger pool of energy for conversion into animal products and ensures a competitive advantage for the species, thereby enabling it to persist. Reservations have, however, been expressed (Williams et al. 1976) regarding the emphasis given to productivity in most tropical grass selection programs because of the inverse relationship it bears to feeding value and of the need to provide conserved feed of acceptable quality for off-season feeding.

(b) Persistence of a pasture plant is a reflection of the extent to which it is adapting successfully to the environment and also of the plant's perenniality (by seed and/or vegetative means), which is dependent on the plant's reaction to grazing, environmental extremes (e.g., drought or frost), and to insect and disease attack. The importance of persistence lies in the fact that durable pastures will bring more returns to the farmer than pastures that need frequent resowing.

(c) Feeding value -- the efficiency of conversion of tropical pastures to animal products is often limited by the quality of the pasture plants. Feeding value will, therefore, be an important attribute in most tropical pasture germ-plasm evaluation programs.

(d) Ease of establishment -- seed production is generally lower in tropical grasses than in temperate grasses (Jones and Roe 1976). Because the large-scale development of pastures will, almost invariably, involve the use of large quantities of seed or vegetative propagules, the potential for seed production or ease of vegetative propagation is an important character to assess in the course of tropical pasture germ-plasm evaluation. Similarly, permanence of a pasture depends, in part, on the ability of the sown species to regenerate from self-sown seed or by vegetative means. Poor seeding and/or limited vegetative propagation will, therefore, limit the use of a species on a large scale.

(e) Associative ability -- because species and varieties differ in their seasonal growth cycles and in their responses to management and environment, mixed pastures should be expected to provide better animal nutrition than pure stands and also to buffer the effects of environmental changes. Identification of compatible species and varieties (intended especially for grass/legume mixed pastures) for given localities, therefore, deserves attention in pasture germ-plasm evaluation programs.

Experimental Methodology

Objective evaluation is the guiding principle in planning the methodology to be used in the various experiments of an evaluation program. An awareness of the possible sources of experimental error (i.e., extraneous variations that tend to mask the effects of experiment treatments), of the ways and means for controlling such error, and of other devices for enhancing precision in experimentation enables the investigator to plan a methodology that will ensure the successful achievement of the aims of the program. These aspects are adequately covered in most standard statistical textbooks (e.g., Cochran and Cox 1957; Steel and Torrie 1960; Little and Hills 1978), but they are summarized here for convenience.

Experimental error arises from two main sources: the inherent variability in the experimental material to which treatments are applied (e.g., a piece of land or a group of steers in grazing experiments), and the lack of uniformity in the physical conduct of the experiment (e.g., inconsistency in the sampling procedure). The following devices are often used to reduce error and improve precision in field experiments.

(a) Randomization -- alloting treatments to experimental material in such a way that each treatment has an equal chance of being tested under more or less favourable conditions. It enables the investigator to avoid biases by ensuring that a treatment will not be continually favoured or handicapped in successive replications by some extraneous source of variation, known or unknown. The general rule is that the investigator should take the trouble to randomize even when it is not expected that there will be any serious bias from failure to randomize.

(b) Replication -- a treatment is replicated when it appears more than once in an experiment. Replication reduces experimental errors associated with the difference between the average results for two treatments provided that other precautions (e.g., randomization) have been taken. Tables are available (Cochran and Cox 1957) for estimating the number of replications required to detect a specified difference between treatments. Replication in time (over several years) and space (in different locations) makes possible an evaluation of the effects of years and different environments on the treatments, thereby broadening the scope of inference of the experiment.

(c) Selection of treatments and treatment combinations -- careful selection of treatments and treatment combinations will, in some experiments, make it possible for the investigator to plan tests of significance that are more sensitive than a mere comparison of adjacent means in any array. For instance, in studying the response of grass species to nitrogen fertilizer rate it is useful to select doses in equal increments covering not only the rates used in practice but also the range of the response expected so that response curves may be compared.

(d) Selection of experimental material -- selection of experimental materials can make a significant difference in the precision of many types of experiments, especially in animal production trials (discussed in more detail later). In some cases, selection of materials actually used in practice increases the scope of inference of the experiment.

(e) Refinement of technique -- a faulty technique may not only increase experimental error, but also result in measurements that are consistently biased. A good technique aims to: (a) uniformly apply treatments, (b) control external influences so that all treatments are comparably affected, (c) devise suitable and unbiased measures of treatment effects (this may involve a preliminary investigation comparing several alternative measures), and (d) prevent gross errors (e.g., through adequate supervision of assistants and scrutiny of data from every experimental unit by the investigator).

(f) Selection of the experimental unit -- the size and shape of the field plot affects precision. Generally, variability decreases with increasing plot size up to a limit beyond which precision declines rapidly with larger sizes. The shapes and sizes suitable for various types of grassland experiments have been discussed in detail by Brown (1954).

(g) Additional measurements and data analysis techniques -- are often used to remove sources of variation among experimental units. In a grass species trial, in which there is wide variation in plant density between experimental units due to differences in seed viability, covariance analysis can be used to estimate the extent to which treatment effects were influenced by seed viability differences. The adjusted responses to treatments represent, approximately, the response that would be obtained if all the experimental units had the same initial plant density. Where the effects of variation are such that data does not conform to the assumptions underlying the analysis of variance the data may be subjected to a transformation prior to the analysis of variance.

(h) Selection of experimental design -- the basic principle in setting up experimental designs consists in assigning treatments randomly to a predetermined set of experimental units and grouping the units in such a pattern that some of the natural variation among experimental units within each group is eliminated from the experimental error. The completely randomized design, the simplest type of design, is set up by allocating treatments at random to a previously determined set of experimental units. If the experimental units form a heterogeneous batch they can be grouped such that units within any one group (called a block) are uniform. This design, one of the simplest designs used in field experiments, is called the randomized complete block design. In the Latin squares design, the treatments are arranged in blocks in two different ways: by rows and by columns such that each treatment appears once in every row and once in every column. The design can be used to advantage in field experiments where there are two main sources of variation (e.g., soil differences in two directions).

In the randomized block design precision decreases as the number of treatments increases (i.e., variation between experimental units increases). This loss of precision can be avoided by forming groups of experimental units that do not contain all the treatments. In this way, each group remains small and contains more uniform experimental units. These groups, called incomplete blocks, can be used to construct other designs to suite particular experimental needs. One such design frequently used in field experiments is the split-plot design in which the basic principle is that levels of one treatment factor are assigned to main plots arranged in a completely randomized, randomized complete block, or latin square design, and the levels of a second factor (or several factors) assigned to subplots within each main plot. The design sacrifices precision for comparing the average effects of main plot treatments but improves the precision for comparing the average effects of subplot treatments.

Many, more complex designs are described in statistical texts. The basic rule in selecting experimental designs, however, is that the simplest design that meets the needs of the occasion should be used. Assistance should be sought if necessary.

EXPERIMENTAL PROCEDURES AND DESIGNS

Three main stages have been identified (Shaw et al. 1976; Whiteman 1977) in the process of pasture germplasm evaluation: preliminary evaluation in the nursery, evaluation under field sward conditions, and animal production trials. These stages need not, however, be taken in sequence in every situation. Sands et al (1970), for example, evaluated nearly 100 known grasses and legumes, under field sward conditions with periodic grazing, in the semi-arid areas of Kenya and recommended 15 grasses and three legumes for animal production trials. The procedure used at Kitale Grassland Research Station, Kenya in the 1950s (Strange 1958), on the other hand, included four rather than three stages.

Preliminary Evaluation in the Nursery

The nursery stage is necessary where accessions need to be described and classified, seed or planting material has to be bulked for further work, or there is little information on the performance of the accessions in a particular environment.

Procedures for the establishment of a nursery for tropical pasture germ plasm have been described in detail by Kretschmer (1979), so they will not be repeated here. However, one aspect that needs careful consideration is selection of the site that should, as far as possible, be representative of the region for which pastures are to be developed. If the region is heterogenous several sites should be selected, one on each of the predominant soil groups. Replication of plots is desirable but lack of seed, too large a number of accessions, and space and labour constraints are frequent limitations. Inclusion of several plots of a "control" species (one whose performance is known in the region) in the nursery is useful for comparison with new introductions.

Visual assessments are made monthly (or more frequently if desired) and records kept throughout the growing season on a number of parameters including (a) growth habit; (b) vigour; (c) leafiness; (d) flowering characteristics, especially time of flowering and length of flowering period; (e) seeding ability and characteristics; (f) incidence of pests and diseases; (g) effects of high and/or low temperatures; (h) nodulation, in the case of legumes; and (i) dry matter yield per plant (may also be assessed by cutting). Descriptors such as those proposed by Kretschmer (1979) and/or scores can be used in recording the observations, but consistency of techniques is essential in minimizing experimental error. Assessments in the nursery are continued for 1-3 years, although some workers (e.g., Williams et al. 1976) consider 3 years to be the minimum period.

Data may be analyzed statistically where circumstances allowed replication of plots in the nursery and assessments are in numerical form. Where there is no replication, or assessments are in the form of notes rather than numbers, analysis is necessarily subjective and, thus, much of the success of evaluation at this stage depends on the experience and intuition of the investigator. Nevertheless, this approach has been used successfully in most of the preliminary evaluation programs in the tropics (e.g., Horrel 1958; Strange 1958; t'Mannetje 1964).

A recent approach to the objective analysis of data collected during preliminary evaluation, especially in programs with large numbers of accessions, is by the use of pattern analysis techniques (Sandland et al. 1976; Williams et al. 1976). They are used to abstract a pattern in the variation and sharpen the definition between accessions from a mass of numerical agronomic and/or morphological preliminary evaluation data, thereby making possible an objective selection of accessions most likely to justify more extensive trials. The techniques, which need the use of computers, have been successfully applied in the preliminary evaluation of large numbers of *Stylosanthes* accessions in Australia (Burt et al. 1971; Edye et al. 1973; Williams et al. 1973).

A serious shortcoming of preliminary evaluation in the nursery is that often much reliance is placed on the performance of accessions under (nursery) conditions that may not be representative of the areas for which improved pastures are required. Wallis et al.(1977) have described a technique developed in Australia that, they claim, overcomes this shortcoming and allows relatively large numbers of plants to be tested on several sites of different climates and/or soils using small quantities of seed and small areas.

Evaluation Under Field Sward Conditions

The objective of evaluation under field sward conditions is to sort out further the more promising accessions from material that was found to be promising during preliminary evaluation. The measurements of performance are still the general characteristics sought in pasture plant species referred to earlier, taken in conjunction with the specific objectives of the program and factors of special local importance. Potential feed value is also usually assessed at this stage.

The field procedures basically involve the establishment of accessions in swards on, preferably, more than one site (each site representing one main type of environment within the region intended for improved pasture establishment). Nutrient deficiencies are eliminated, as far as possible, by correct basal and maintenance fertilizer applications. Legumes are usually grown mixed with a grass suited to the area because they soon become invaded by grass weeds if they are established in pure stands. The plot size is determined largely by the technique for estimating yield, species growth habit and the availability of resources, but may be as small as 4 m^2 and need not be larger than 100 m^2 (Shaw et al. 1976). The number of replicates established at one time at each site will range from two to six depending on the degree of precision required (GRI 1961). Nonreplicated experiments have been conducted in some cases (e.g., Bogdan and Mwakha 1970), but they are only useful when large differences between treatments are to be expected or seed is in short supply.

The choice of experimental design is influenced mainly by the type of land and the type and number of treatments and treatment combinations. However, the randomized complete block design has been used in most experiments (t'Mannetje 1964; Naveh and Anderson 1966; Jones et al. 1967; Edye 1975). Another common design is the split plot design (Kleinschmidt 1967; Bogdan and Mwakha 1970; Jones 1974).

A range of treatments can be imposed on the pastures depending on the priorities of the evaluation program. The most important ones include those that introduce (a) stress effects of competition between species (i.e., comparisons between pure stands and mixtures and among mixtures), (b) stress effects of nutrients (i.e., response to applied nutrients), (c) stress effects of defoliation (i.e., response to cutting and/or grazing, and (d) stress effects of soil moisture (i.e., response to seasonal fluctuations in soil moisture content and/or irrigation). Effects of defoliation stress are particularly important to study at this stage because pasture utilization involves repeated defoliation of the pasture plants. Even where defoliation effects are not specifically examined in an experiment, an assessment of species tolerance to defoliation can be obtained by subjecting the plots to grazing and then mowing (to remove uneaten residues) after each yield sampling and monitoring sward vigour throughout the duration of the experiment.

Although the measurements taken are broadly the same as those during preliminary evaluation, assessment under field sward conditions is more rigorous and precise. Visual assessment becomes replaced by more refined technques: (a) productivity (both annual and seasonal) is assessed by regular quadrat or strip cuts from the plots; (b) sward vigour is assessed through estimates of botanical composition to monitor the ingress of weeds; (c) persistence of the sown species is estimated by plant counts at establishment and, subsequently, at each yield sampling; (d) potential feeding value is estimated by determining in vitro digestibiity, chemical composition, intake with caged sheep, and preference by grazing animals. For legumes, measurements should also be taken on effectiveness of nodulation and tolerance to pests and diseases to which they are more susceptible than grasses (Shaw et al. 1976).

Where the objective of the evaluation program is to select material for natural grassland improvement through oversowing, research at this stage will be concerned mainly with methods of oversowing and establishment of the oversown species. Possible treatments include (a) methods of seeding, (b) seed rate, (c) pretreatment of existing pasture, (d) seed treatment, (e) fertilizer application, (f) defoliation management, and (g) seeds mixtures. The designs commonly used in these experiments are the randomized complete blocks (Warboys and Johnson 1966), randomized complete blocks with factorially combined treatments (Keya et al. 1971; Keya and Kalangi 1973; Keya and van Eijnatten 1975), and split plots (Keya et al. 1972).

Statistical analysis of data from field sward evaluation experiments is done in accordance with the model appropriate for the experimental design chosen.

Animal Production Trials

The main purpose of evaluation at this stage is to assess the potential of promising species, under actual grazing conditions, in terms of animal production. t'Mannetje et al. (1976) have stressed the importance of clearly defining the objectives of animal production trials because they (the objectives) affect the choice of treatments, experimental design, and size of the trials. The following points need to be considered in formulating experiment objectives:

(a) Enterprise for which improved pastures are required (beef production, milk production, or wool production),

(b) History of the animal production industry (i.e., whether the industry already exists in the region or is to be introduced for the first time),

(c) The place of improved pastures in the overall feeding plan (i.e., whether improved pastures will be the sole source of feed or they will supplement other sources including crop residues and natural pasture), and

(d) Problems being studied and their relevance to the animal production industry in the region.

Choice of treatments. The priorities of the evaluation program will determine the type and number of treatments chosen, but the most frequent ones include (a) effects of grass or legume species in pure stands (Stobbs 1971; Stobbs and Sandland 1972), (b) effects of pasture mixtures (Okorie et al. 1965; Stobbs 1969b), (c) effects of fertilizer rates and/or stocking rates (Stobbs 1969b; Tiharuhondi et al. 1973; Mears and Humphreys 1974), (d) effects of grazing frequency (Stobbs 1969c), and (e) effects of oversown grass and/or legume species (Stobbs 1969a; Otim 1975). Management factors that are not treatments (e.g., grazing methods or supplementary feeding) are applied uniformly to avoid confounding the results and interpretation.

Several workers (Wheeler 1963; Owen and Ridgmen 1968; t'Mannetje et al. 1976) have emphasized the need to include a series of stocking rates in grazing experiments, irrespective of the objectives of individual experiments. An ideal range includes a minimum of three stocking rates with one above and another below the optimum rate. t'Mannetje et al (1976) have suggested a guide that can be used to select stocking rates in areas where the optimum rate is not known.

Choice of animals. Animals used in grazing experiments should be those whose genetic and physiological ability allow full expression of treatment effects. The number of animals required for precise measurement of treatment effects depends on the size of the treatment difference it is desired to detect, the degree of variability expected and the confidence levels required. Tables are available (Cochran and Cox 1957) for estimating the number of animals required.

Uniformity of animals used in grazing experiments is important, and some workers (e.g., Wheeler 1963) have suggested the use of divided pairs of monozygotic twins as a means of reducing genetic variability. In most cases, however, such animals are not readily available and the investigator has to rely on careful selection on the basis of age, liveweight, breed, previous performance, and stage of lactation, in the case of dairy animals.

Experimental designs. Factors that influence the choice of the design and lay-out of grazing experiments have been discussed by many workers (Brown 1954; GRI 1961; Owen and Ridgman 1968; Wheeler 1963). The more important factors include the following:

(a) Limitations of land (availability, topography, soil fertiity) and pasture (grazing potential),

(b) The need for an unbiased estimate of error,

(c) Choice of treatments to be compared and response factors to be measured,

(d) The need to achieve maximum experimental efficiency without sacrificing good practical management,

(e) The possible duration of the experiment -- 3 years is usually considered to be the minimum period although experimental objectives may required a longer or shorter period,

(f) The financial and labour costs and the likely benefits in terms of practical importance and knowledge, and

(g) The possibility of establishing the experiment at several sites to cover climatic and edaphic variability, or the possibility of coordination with other experiments.

The randomized complete block design has been used in simple grazing experiments, for instance, in comparisons between grass/legume mixtures (Okorie et al. 1965). The design is efficient where few treatments are tested and differences in soil fertility are small. As the number of treatments increases, the area of land required and the likelihood of uncontrolled soil fertility variation also increase. A factorial combination of treatments allows measurement of treatment x site and treatment x treatment interactions. Mears and Humphreys (1974), in Australia, used a factorial randomized block design in an experiment in which the effects of nitrogen fertilizer application and stocking rate on the productivity of a Kikuyu grass pasture were assessed.

The split plot design has been used in experiments where the application of a treatment is difficult on scattered plots, or where extra treatment factors are introduced in an experiment already in progress. For example, in an experiment assessing the effects of nitrogen fertilizer application and irrigation on beef production from a mixed grass pasture in Uganda, Tiharuhondi et al. (1973) used a split plot design in which two irrigation levels were the main plots and four nitrogen fertilizer rates formed the subplots.

In experiments with dairy animals where considerable variation often arises from performance characteristics of individual animals (i.e., milk yield is influenced by stage of lactation and age of the animal), Latin square change-over designs have been used to reduce experimental error (Jeffrey 1970; Stobbs 1971; Stobbs and Sandland 1972). They allow comparison of treatments on a within-cow basis thereby eliminating between-cow differences in production level from the experimental error. The basic pattern of these designs, is illustrated by Lucas (1957).

One shortcoming of the change-over designs is that performance on one treatment may be affected by previous treatments in the same sequence. However, Jeffrey (1970) concluded that periods of 4 days are adequate for most grazing experiments conducted with dairy cows where either very large treatment effects or large dietary differences do not exist. Lucas (1957) described an "extra period" Latin square change-over design that removes carry-over effects of treatments.

The designs outlined in the foregoing apply to replicated experiments. Sometimes nonreplication is unavoidable or desirable. A design in which the tester (beef) animals are blocked and allowed to graze the treatment paddocks rotationally, with a different set of animal blocks being used each year, has been used in several pasture evaluation trials in East Africa (Stobbs 1969a,b,c; Otim 1975). Treatments are compared by testing for significant differences in slopes of the estimated regression lines for cumulative animal production. Continuation of the trials for several years and the use of different animal blocks each year gives some measure of replication.

Measurements of performance. Two main types of measurements are taken in animal production trials: animal performance and pasture performance measurements. The former include liveweight gain, milk yield and quality, body measurements and condition scoring, and carcass quality and reproductive performance.

Pasture performance measurements include dry matter (annual and seasonal) yield, carrying capacity, botanical composition, persistence, chemical composition, feeding value (in vitro or in vivo digestibility and intake), and soil fertility changes. Procedures for taking these measurements have been described (Brown 1954; GRI 1961; Minson et al. 1976; Shaw et al. 1976).

An additional, but important category of measurements at this stage of germ-plasm evaluation comprises those that make possible some economic assessment of the treatments. In an experiment designed to examine the effects of nitrogen fertilizer and irrigation on beef production from a mixed grass pasture in Uganda, Tiharuhondi et al. (1973) also compared treatment effects in terms of costs and returns, net gain in value of beef per hectare, and conversion ratio (kg beef/kg nitrogen applied).

CONCLUSION

It is clear from the preceding sections that a germ-plasm evaluation program is, of necessity, widely spread in time (it requires many years to produce conclusive results) and in space (includes several sites in different environments). Frequent communication between scientists on the program (e.g., through regular workshops to review progress), therefore, helps to ensure that unforeseen problems and developments are discovered and necessary modifications are made in the program in good time. Similarly, collaboration with researchers on other pasture and livestock programs in the region enables scientists on a germ-plasm evaluation program to broaden their knowledge on problems affecting the grazing industry and can, therefore, reorient their program accordingly.

The multiplicity and variety of activities involved in a germ-plasm evaluation program imply that:

(a) A multidisciplinary team of scientists has to be assembled for the successful execution of the program (an effective team is likely to include an ecologist, a botanist, an agronomist, an animal nutritionist, a soil scientist, a statistician, and a socioeconomist),

(b) Considerable amounts of money have to be invested in the program, and

(c) Quantities of various materials have to be secured (e.g., specialized equipment, literature, and animals).

These requirements are likely to be beyond the capability of individual countries in tropical Africa where a shortage of both financial and scientific personnel resources is widespread. In these countries there is, therefore, a strong case for joint programs in which groups of countries pool their resources to set up a central laboratory and field station (each station representing a major type of environment or livestock production system) at which field sward testing and animal production trials are conducted.

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INTRODUCTION AND EVALUATION OF LARGE GERM-PLASM COLLECTIONS

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Abstract *The framework is given within which to conduct a program for the assembly and evaluation of a collection of pasture plants. Aspects dealt with include objectives of the program, whether to breed from the collection or select for direct use, how to carry out the preliminary and detailed evaluations, maintenance and seed increase, determination of the areas of adaptation, and commercial release.*

The assembly and evaluation of collections of tropical pasture germ plasm have been well described in the literature over recent years. The material available ranges from individual chapters, such as Williams (1964), Shaw et al. (1976), and Williams et al. (1976) in more general books on tropical pasture research, to specific books on the subject, e.g., Mott (1979) and Clements and Cameron (1980). As well, McIvor and Bray (1983) discuss the whole subject of the genetic resources of forage plants.

These publications detail the different approaches that can be taken to the assembly of a collection and its subsequent maintenance and evaluation. They show different approaches, that may, at first sight, seem difficult to reconcile. These differences arise for various reasons, including different objectives of the programs, different types of material being handled including the different breeding systems, different levels of facilities available to conduct the programs, and last, but by no means least, different philosophies as to how such an evaluation should be undertaken.

It is not my intention to attempt to reconcile these various approaches, but rather to present a framework (Fig. 1) within which rational decisions can be made as to how to tackle the particular problem at hand.

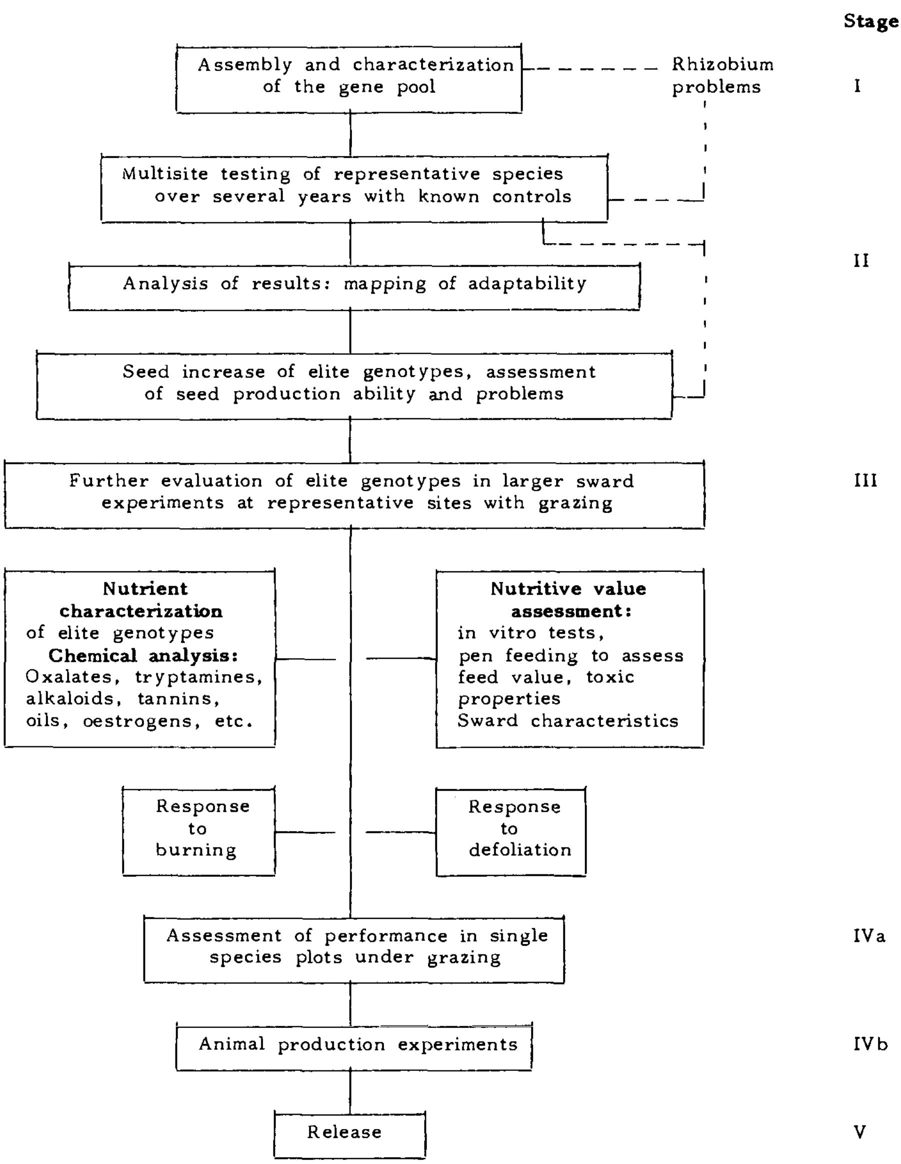

Fig. 1. Scheme for evaluation of introduced pasture species (source: Jones and Walker 1983).

DETERMINATION OF OBJECTIVES

One of the most important steps is to define clearly the objectives of the program. This will affect the approach taken both in assembly and in evaluation phases. Is the objective to provide a complete suite of pasture plants for use in an area where sown pastures have not previously been used, or is the objective simply to refine an existing array of cultivars, some of which are deficient in certain features, such as ease of establishment, palatability, or productivity? Is the objective to plug gaps in an existing array by providing plants for special uses, such as legumes for use on heavy clay soils, or has a widely used and valued plant broken down due to the advent of a new disease or insect pest? All these objectives require collections of greater or lesser complexity to be assembled. If a breeding program is required to provide a new disease-resistant cultivar, the collection may be monospecific. If full-sown pastures were required for an area where presently there were none, then both grasses and legumes and possibly even forage crops will be required. For this, a very broad-ranging collection will be assembled.

The nature of the local livestock industry and the size of the area to be serviced will also influence the defined objectives. Different plants are required where livestock feeding is by "cut and carry" as opposed to extensive, free-range grazing. Similarly, a much more extensive collection will be necessary if a large area is to be serviced rather than just a restricted locality.

BREEDING VERSUS DIRECT USE

There is great fascination, in some quarters, with plant breeding as a means of providing new forage plants, but breeding in pasture plants can be much more difficult and less rewarding than for crop plants. Unless there are very specific and clear objectives, such as inducing fertility in valuable, but sterile, material, or transferring disease resistance, pasture plant-breeding objectives are difficult to define and even more difficult to achieve. Dry matter yield is a poor objective. The inefficiencies in conversion of dry matter to animal product mean that rather large differences between yields of pastures often give virtually no differences in animal product. Differences in various characteristics (e.g., seasonal production pattern, digestibility, palatability and hence diet selection, and forage quality) tend to nullify differences in dry matter yield. A low-yielding, persistent plant is often more useful than a high-yielding one that is not well-adapted to the local pasture ecosystem and so has to be very carefully managed or one that produces its main bulk at a noncritical time of the year.

Before a breeding program can be implemented, the collection of available material has to be evaluated and the strengths and weaknesses of every accession assessed in an agronomic as well as a genetic sense. It is often a short, and much quicker, step to take the best of the collection directly into pasture use. Breeding is a slow, time-consuming activity. Representative variability of the species to be bred must be available, but reproductively incompatible plants cannot be used. This latter feature tends to restrict those lines being taken through the preliminary stage. This stage is identical for either breeding or direct use, so material with potential for direct use is excluded from the preliminary evaluation phase.

It is recommended that, for developing areas, the initial approach should be to provide new pasture plants directly from the naturally occurring genotypes of all potentially useful species. Breeding programs should be undertaken only where locally valuable plants have collapsed under pest or disease stresses, or are showing some clear and readily corrected defect. The first requirement for a successful breeding program is a well-qualified, enthusiastic plant breeder. Breeding programs have a habit of developing into exercises in genetic science that have little value in practical plant-improvement programs.

ASSEMBLY OF A COLLECTION

Before collection of material begins, the objectives should be defined and two other points attended to:

(a) Assemble a full description of the environment of the target region(s) in which the selected material is to be used. This applies especially to climate and soils. Similar areas in other countries should be sought as sources of material for test (Reid 1980). If this can be done, it can substantially reduce the number of unsuitable lines included in the collection and so reduce the work involved in its evaluation.

(b) Become thoroughly familiar with your local plant import and quarantine requirements. This ensures the smooth entry of all material without any losses arising from failure to meet all import formalities. Quickly establish a working relationship with the appropriate officials so that they know you and the objectives of your program.

If there are no or few quarantine requirements, give consideration to establishing such a system within your program. This ensures that no unwanted pests and diseases come in with seed or planting material (Jones 1980). Ensure that material being included in the program has no local weed potential. A good maxim in this regard is "if in doubt - out" take in only material that you are sure is disease-free or has no weed potential and destroy all other samples.

The defined objective will determine the scope and complexity of the collection that needs to be assembled. There are four major sources of seed:

(a) Commercial trade: For areas where sown pasture development has not been attempted previously, the first step is to examine all commercial material, available in other countries, that may suit your local environment. This material is already domesticated and ready for commercial use if it proves adapted. The source can be the commercial seed trade. Samples can be as large as can be afforded.

(b) Major international collections: There are now a number of major germ plasm collections, such as those at Centro Internacional de Agricultura Tropical (CIAT) in Colombia, Empresa Brasileira de Pesguisa Agropecaria (EMBRAPA) in Brazil, International Livestock Centre for Africa (ILCA) in Ethiopia, and Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. They will provide small experimental samples of seed, especially if you are able to supply exchange samples of local material or material from other sources not already in their collections. Correspondence with the Officers-in-Charge of the collections is all that is required. Some of these centres will also provide small quantities of local commercial seed. A detailed description of your target environment will help them select material to forward to you.

(c) Smaller institutional collections: Most research centres involved in plant impovement maintain some sort of a germ plasm collection, even if it is only their current working stock. They are usually quite willing to provide small samples and can be most useful, especially if located in areas already determined as matching your target area. They often have local ecotypes, not yet in the major collections. Correspondence is all that is required.

(d) Field collection: This can be a simple assembly of all the more promising wild ecotypes within your local region(s), or those collected on an extended international collecting trip. Either way, the procedures are the same. (See the relevant chapters on preparation, collection, and data recording in Mott (1979) and Clements and Cameron (1980).) The local material should be assembled as a matter of course early in the program, both for formal testing and use as control lines and for use as exchange seed with outside collections. The major international collecting trip is more of a last resort. Unless it can be associated with other major reasons for travel, it should be undertaken only when other possibilities have failed to provide useful material.

GERM-PLASM MAINTENANCE

At the beginning of the program, attention should be given to maintenance of the germ-plasm stocks as they are assembled. This is necessary both before and after the particular lines have been evaluated. It is often necessary to return to the original sample, if only to check that a confusion of identities has not occurred somewhere during evaluation. This happens even in the best-run programs. For this purpose, two factors require attention: a numerical register of all samples should be established to identify individual seed lots, and a secure seed storage facility should be developed.

Storage should provide protection against vermin and insect damage and provide cool dry conditions conducive to maintenance of viability. Seed under ambient conditions in hot-humid areas will lose its viability in less than 12 months. A cool, dry cellar, suitably vermin- and insect-proofed, can serve this purpose. It will give some years of life to the seed. It should be possible to retrieve seed quickly from the store whenever it is required.

No matter what storage is available, arrangements should be made for periodic regeneration of the stocks and, more important, for the increase of selected samples for further testing. Regrowing should take account of the isolation needed to maintain the genetic integrity of the samples (Luse 1979; Williams et al. 1980).

PRELIMINARY EVALUATION

The preliminary evaluation of any collection is routine, no matter what the future intention for the material. It is a familiarization process to get to know the strengths and weaknesses of each species and accession. It should be carried out as soon after receipt of samples as possible. Preliminary evaluation is not only a detailed recording of various characteristics of the individual accessions but also the development of a personal understanding of the material, often in a most unscientific but very useful fashion. It can commence in the quarantine glasshouse if the material is accessible at that stage.

The technique used will depend on the quantities of seed available. For very small samples, care should be taken to ensure establishment of each individual seed. Barriers to germination, such as hard seed coats or dormancy, should be removed. Protection from diseases and pests should be provided and ideal germination conditions used. Seedlings are frequently raised in individual pots (used paper drinking cups are useful) and planted out into the field as spaced plants. Where larger samples are available, they can be planted directly into the field, in solid nursery rows. Either way, it is wise not to use more than half the seed available at each attempt at establishment. Probably, only one planting a year will be possible.

The nursery should be on an even area, free from changes in soil texture and fertility, and be well-drained and weed-free. A thorough seed bed preparation should be carried out and adequate base fertilizer applied before planting. Any weeds that do appear should be promptly removed. Irrigation should be available, unless rainfall is very reliable, to ensure establishment of all material planted, but no irrigation should be used after establishment. Legumes should be inoculated with appropriate rhizobia or arrangements made for regular light applications of nitrogen fertilizer (25 kg N/ha/month) to ensure growth potential is reached. This also applies to accessions that fail to nodulate despite inoculation. A search should then be initiated for suitable rhizobia. At all stages through the evaluation, similar local plants should be planted as standards against which to assess the performance and likely future value of test material.

Where possible, replication should be used, but this is often omitted at the initial nursery stage. Arrangements should also be made for initial seed increase for future testing. Allowance will need to be made for the breeding system of the plants in the allocation of material to plots within the nursery. A few accessions of one cross-pollinating species can be distributed widely through the nursery without too much risk of genetic contamination, but a large number of potentially crossing lines of one species may require separate isolated sites for seed increase.

Note-taking should be frequent and comprehensive at this stage and is facilitated by an appropriate data sheet prepared in advance of the first recording. These should cover the characteristics considered most desirable to record for local purposes plus initial establishment. For at least 2 years and preferably longer, flowering time, drought, frost, insect and disease reactions, habit of growth, leaf and stem peculiarities, seed set, holding and shattering, seed size, potential seed production, and plant and stand persistence should also be recorded. Retain the nursery for as long as possible, allowing animals periodic access in later years, noting plants not readily grazed. See Mott (1979) and Clements and Cameron (1980) for several possible types of forms and full details of initial evaluation.

At this stage, the species identification of all samples should be confirmed or adjusted as far as is possible. All potential weeds that have slipped through earlier screenings should be removed. Where there are a substantial number of accessions of one species or genus within the collection, efforts should be made to classify these into like groups. This classification can be a simple intuitive grouping of lines or a highly sophisticated computer exercise. Its objective is to allow the reduction of the number of accessions that have to be grown in the next phase. It is carried out, if possible, at the end of the preliminary evaluation phase.

DETERMINATION OF AREAS OF ADAPTATION

Where the primary nursery is serving a large area, as much of the material as possible should then be planted widely throughout that area. Where groupings of very similar lines have been made, only one or two representatives of each group need to be taken further at this stage. If these turn out to be extremely promising at certain sites, then further representatives of that group, or even the whole group, can subsequently be grown at those sites.

The methods used for this determination are relatively unimportant, ranging from simplified nursery techniques, to cultivated strips in native grasslands, or even small swards. See Cameron and McIvor (1980) for the cultivated strip technique (Fig. 2) that has been found useful in northern Australia. The important point is to standardize between sites to enable direct comparison across all sites. Note-taking in this phase is much reduced relative to that in the main nursery. This phase permits the assessment of what lines are likely to prove useful in different areas. Some will show wide adaptation and continue, initially, to be grown widely. Others will show only localized value at a few closely related sites, e.g., on wet low-lying land. At the end of this stage the collection should be grouped into categories of differing adaptation and potential uses.

DETAILED EVALUATION

Once areas of adaptation within the collection are known, the numbers of accessions tested further at

Fig. 2. Establishing a legume strip in native grassland for experimental evaluation.

each centre can be drastically reduced. Depending on the resources and facilities available, evaluation may be concentrated in a few of the more important districts or may be continued widely through the region. It may concentrate on grasses at one centre and legumes at another, or on different legume genera at different centres. Until this stage has been reached, little quantitative data will have been collected. Now the best 20-30 accessions can be subjected to detailed assessment for final selection. The techniques used and measurements made will be influenced by the objectives set out

Fig. 3. Small-plot cutting trials with grasses at South Johnston Research Station in Queensland.

before the program commenced. Proceed through all or some of the following stages.

(a) Small-plot, cutting trials (Fig. 3): Usually monospecific, these permit seasons of productivity and reaction to defoliation to be assessed. Plots are small, 2 x 2 m or less if seed is in short supply. Some plants may require larger plots. Due to the removal of cut material and the drain on soil fertility, fertilizer applications should be heavier than those that are made on grazed plots. Measurements will include establishment and persistence of plant populations, periodic dry matter yields, and ingress of weeds.

(b) Small-plot, grazed trials: These may be somewhat larger plots, which are grazed after each yield assessment is made (from a small sample area), to give a better pasture environment for assessment. Relative palatabilities, in particular, should be noted. Duration of these trials should be at least 4 years to give some assessment of persistence under grazing.

(c) Legume/grass compatibility: These trials can involve either all legumes with a standard grass and vice-versa or a legume/grass grid in which the legumes under consideration are planted in long narrow strips in one direction with the promising grasses in similar width strips at right angles. Each grass x legume segment should be assessed separately. Five legumes x 5 grasses gives 25 separate subplots to measure per replicate, so numbers are large if the grass and legume accession numbers are high. A minimum of three replications should be used for all trials in this phase. (For further details see Cameron and McIvor 1980.)

Any problems such as establishment difficulties or special nutritional requirements should be investigated at this stage and a solution identified before the material is taken into further detailed studies. Close attention should be given to any seed production problems (Hopkinson and Eagles 1980).

GRAZING ASSESSMENT

The grazing should provide a final assessment of the true worth of a pasture plant but poses questions that are very difficult to answer. It is rarely possible to simulate, in grazing studies, the type of use to which practical farmers will subject their pastures. As a result, the final determination of worth can come only from commercial use. It is not proposed to describe grazing trials in detail here (see, for example, 't Mannetje et al. (1976) and Jones and Walker (1983)), but careful thought should be given to matching the local use patterns as far as possible, using local types of livestock and grazing management regimes. A range of stocking rates should be used.

The more sophisticated the local pastoral industry, the greater the need for grazing studies in the final selection process. Minimum monitoring is that of animal product alone, milk yield, or liveweight gain, but, where possible, pasture parameters should also be measured to know what is happening in the pasture (Cameron and McIvor 1980).

SEED INCREASE AND RELEASE TO COMMERCE

At the time the first seed stocks are made available to commercial seed producers, a cultivar name should be selected and publicized. Before this release can occur, the initial seed stocks have to be increased.

The initial commercial phase is often handled by a seed increase committee with representatives drawn from the agronomists, seed producers, seed merchants, and farmers. This committee will supervise production techniques and disposal of seed by the first commercial seed producers (Hopkinson 1980).

It is at this stage that consideration should be given to the need for seed certification. With many tropical species, such as apomictic grasses, it is generally not required, especially if they have easily recognizable features. Seed certification is an expensive and time-consuming activity that should be avoided if possible. When there are several potentially cross-pollinating cultivars in production, seed certification becomes essential.

During the precommercial increase phase, there will be seed stocks that are of inadequate quality for further multiplication purposes. However, these contaminated stocks can be used to familiarize extension officers and landholders with the new material. They can be used for demonstration plantings throughout the areas where it is intended to use the new cultivar.

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METHODS OF PASTURE ESTABLISHMENT

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Abstract *Establishment of pasture plants is probably best studied by sowing seeds under the conditions they are likely to encounter in agricultural practice and counting the survivors. On a more theoretical level, establishment can, however, be regarded as three separate phases - germination, emergence, and survival - and factors likely to affect each of these phases are reviewed. Practical considerations involved in the establishment of pastures are then discussed.*

In this paper, the subject of pasture establishment has been considered from the aspect of the Third World countries with limited resources of staff, finance, and facilities where the need is to apply these resources to greatest immediate advantage. Probably the most appropriate research methodology for examining pasture establishment is to sow the seeds of pasture plants likely to prove ecologically adaptable in situations where they are likely to be agriculturally valuable using methods that are likely to be practical agriculturally and then to determine the proportion of the seeds that give rise to established plants. The number of times that "likely" occurs in that sentence indicates the extent to which local expertise is invaluable in deciding which pasture strains to sow, how they would be used in farming practice and what sorts of technology are available to the farmer.

In Zimbabwe, for instance, different answers would probably apply on a large-scale commercial farm and on a small-scale subsistence one; on a farm on a clay soil and on a farm on sandy soil, and for reinforcement of native grassland as opposed to sowing legumes on arable land. Because of this, it is difficult to outline a single, step-by-step procedure to be followed in all cases. What we have done is to outline the stages between the seed and the established plant and the factors that we consider important in ensuring that the developing plant passes from one stage to the next until it is established. There are always arguments about what can be considered as an "established" plant: under our conditions, where we work essentially with perennial species in an area characterized by distinct wet and dry seasons, we could consider a plant established if it survived into the growing season after that in which it was sown.

Establishment is unusual among the various aspects of grassland research in that laboratory and greenhouse trials can form an important part of the program. Initially, the value of these trials is almost entirely exploratory, although once models have been derived they can be used for prediction purposes. Because of the relevance of laboratory work and because establishment trials are in most cases short-term, establishment studies form a very suitable topic for graduate projects at universities and this is a source of research expertise that should be borne in mind. One danger, although, is that too many trials end at the laboratory stage. As an example, tests of methods of breaking hardseededness in legumes should include field sowings and not merely present petri-dish results.

PRINCIPLES

Ensuring Maximum Germination

Dormancy may be a problem and very low germination is obtained with freshly harvested seed of some grasses. Tropical pasture species, both grasses and legumes, are very recent selections from wild plants and retain a number of survival mechanisms, such as seed dormancy, that have been largely eliminated by selection for rapid germination from the temperature cultivated species. Although it may be possible to overcome dormancy by such treatments as the concentrated sulphuric acid used by Smith (1966a) on Sabi pancium (P. maximum), these are not usually feasible with large lots of seed. It is usually a wise precaution, as recommended by Liebenberg (1955), to sow seed of grass species known to exhibit dormancy only in the second season after harvesting.

Hardseededness is a very common cause of reduced germination in subtropical legumes and among methods used to overcome it are: dry heat (Holm 1973; Anonymous 1977; Mott 1979), hot water (Gray 1962; Phipps 1973; Savory and Thomas 1977), fluctuating temperatures (Quinlivan 1961, 1968; Cameron 1967; Taylor 1981), cold treatments (Phipps 1973), microwave radiation (Nguyen Tran 1979), mechanical abrasion (Grant 1979a, 1980), concentrated sulphuric acid (Phipps 1973; Pentney et al. 1984), and seed coat nicking (Pentney et al. 1984). "Large increases in germination can be achieved that would enhance successful establishment and economise in seed" (Phipps 1973).

The actual method used would depend on the cultivar and the feasibility of the treatment, e.g., dry heat is a very suitable method to use on tobacco farms where barns at the correct temperature are available during the curing season; with peasant farmers, methods using boiling water are more feasible than those that require a lower specified temperature.

Rapid and complete germination of sown species is probably an advantage in sowings on arable land where a suitable seedbed can be precisely prepared, and the relatively small areas can be sown rapidly when conditions are near ideal and when it is essential that sown species establish before weed competition becomes too severe. It may be desirable to retain a proportion of hard seed as an insurance against complete failure in grassland reinforcement projects where there is less control over the conditions and where "false flushes" of germination are more likely to occur. It is likely that, because of the effect of fluctuating temperatures in reducing hardseededness (Cameron 1967), differences in germination between treated and untreated seed will not be as great in field sowing as in the petri-dish.

Trials in which seeds are sown at frequent intervals, preferably over more than one growing season, and the emergence compared with relevant meteorological data, give an indication of the conditions that favour germination and emergence (Smith 1966a). Then, from an analysis of long-term meteorological records, such as those of Lineham (1967), it is possible to predict the time of the season at which these conditions are most likely to occur. The risks inherent in this probabilistic approach can be reduced if accurate medium-term weather forecasts are available to the farmer.

Compaction of the soil around the seed increases water flow into the germinating seed. Compaction can be done with a roller, ideally both before and after sowing the seed (Grant 1976, 1978). The germination of fluffy seeds, such as Buffel grass (Cenchrus ciliaris), may be increased by hammer milling the seed to remove bristles and glumes (Humphreys 1978). Finally, pelleting the seed may increase water uptake by surface sown seeds and so aid germination (McWilliam and Dowling 1970).

Differences occur in the ability of pasture species to germinate under moisture stress. Ryegrass (Lolium perenne), for instance, germinated at suction potentials that inhibited germination of Phalarais (P. tuberosa), Lucerne (Medicago sativa), and Subterranean clover (Trifolium subterraneum), and McWilliam and Dowling (1970) suggested that this might be one of the reasons contributing to the successful establishment of ryegrass from aerial seedings.

Ensuring Maximum Emergence

Numerous greenhouse studies have shown that with small-seeded pasture species, depth of sowing is critical to emergence, and recommendations for optimum depth of sowing range from 5 to 15 mm (Bogdan 1964; Smith 1966a; Stonard 1969; Grant 1975). The reduction in emergence resulting from deeper sowing may differ with soil type (Grant 1975). In a field trial with Tall fescue (Festuca elatior) varieties, Brock (1973) showed that emergence was greater for sowings 15 mm deep than from 5 or 25 mm sowings.

For large-scale field sowings, accurate control of depth of sowing depends on using a precision drill or on the creation of furrows of a suitable depth in which the seed can be placed. This is one of the effects of prerolling with a Cambridge roller (Grant 1979b).

Marked surface crusts can develop on certain soil types - usually those with a high silt content. On these soils, emergence of seedlings can be greatly reduced (Leslie 1965; Brock 1973; Grant 1975), although there is evidence that the reduction may be due to mechanical impedance by the soil and not to the direct effect of the crust (Leslie 1965). On these soils, attempts to compact the soil around the seed may have a harmful effect, especially if a spell of dry weather follows.

The formation of a crust and the mechanical impedance of the soil are greatly reduced if the soil is moist (Grant 1975), and this is one of the reasons for the beneficial effects of a mulch, such as that recorded by Smith (1966b) on a soil very prone to crusting. Rickert (1970) also recorded beneficial effects of mulching on grass establishment, but there was a reduction of grass yield at very high levels of mulch.

There are two ways in which the soil around the seed can be kept moist: by good (or lucky) timing of sowing before a rainly spell and by reducing the loss of moisture from the soil surface. The latter can be done by shading the soil with a mulch (which accounts for the beneficial effects of a mulch on noncrusting soils) or with a cover of vegetation. Thus, McWilliam and Dowling (1970) found that establishment of surface-sown seed was greater under grass that had been killed with herbicide than on bare soil and Miller and Perry (1978) recorded greater germination of Townsville stylo (Stylosanthes humilis) seed under standing grass than on a burnt area.

Leslie (1965) recorded greater emergence of seedlings from soil which that had been sterilized by autoclaving than from control soil and tentatively ascribed the effect to fungal organisms. Treatment of grass seed with seed dressings may be warranted. As most of the pasture legumes exhibit epigeal germination, the effect of seed treatment is less marked and it may interfere with inoculation.

In Leslie's trial (1965), the emergence of Rhodes grass (Chloris gayana) was reduced by surface crusting more than was that of green panic. This does not appear to accord with the results of Smith (1966a) who recorded a much greater response to mulch, in terms of number of seedlings emerged, of Sabi panicum than Katambora or Giant Rhodes grass. There are obviously differences in the ability of different species to emerge under adverse conditions, although, on this limited evidence, the effects do not always appear to be consistent.

Ensuring Maximum Survival

The first stage is the reduction of weed competition by preseeding treatments to eliminate, or reduce the effect of, the existing vegetation. In grassland reinforcement projects, the complete elimination of the vegetation is obviously undesirable and the aim is to reduce the vigour of the existing grasses by heavy grazing and trampling (Edwards and Mappledoram 1973), by burning (Stocker and Sturtz 1966; Chadhokar 1977), by cultivating strips (Clatworthy and Thomas 1972; Mills 1978; Cook and Dolby 1981), or by herbicides (Campbell 1976; Cook and Dolby 1981). Almost invariably the greater the reduction of the native vegetation, the greater the establishment of the sown species (Pearen and Keoghan 1982).

On arable land the aim is the complete elimination of the existing vegetation by several cultivations, and possibly by herbicide application, before the pasture seed is sown. Postsowing treatments that reduce the effects of the weeds include:

(a) Use of herbicides. Most of the herbicides are preemergent and applied either before or immediately after sowing the seed. Examples are Trifuralin (Cameron 1971), Eptam (Grant 1978), Alachlor and Metalochlor (Irvine 1984) for legumes, and Atrazine for grasses. Postemergent herbicides are less commonly used, although 2,4-D is effective against dicotyledonous weeds in grasses and may also be used to control certain weeds in Stylosanthes species (Scanlan 1981).

(b) Weeding or cultivation is greatly eased if the pasture seeds have been sown in drills. Mechanical cultivation is possible on a large-scale but hand-weeding can only be used on small-scale plantings and where labour is very cheap.

(c) Grazing, mowing, or slashing the pasture if weeds threaten to shade the pasture seedlings is often recommended. The treatment must be carefully controlled if the pasture seedlings are not to be damaged.

(d) Underseeding the pasture in a crop, usually of maize, is a practice that offers a number of advantages especially for establishment of legume seedlings (Thomas 1975). Among these advantages is the partial suppression of grass weeds by the maize canopy, allowing the legume seedlings to compete on more favourable terms.

Early nodulation of the legume seedlings helps to make them independent of soil nitrogen and so better able to compete with the grasses. Most of the pasture legume cultivars nodulate satisfactorily with local soil Rhizobium strains and inoculation may prove unnecessary in practice, except for very small-seeded legumes (such as Lotononis bainesii) and those with very specific Rhizobium requirements. However, until it is known which legumes do not need inoculation it is always advisable to inoculate, especially in experimental sowings. Dry cultures of inoculum are readily available commercially and travel well by air freight. Inoculation of legume seeds is a simple process. Instructions are usually included with the inoculant and can be found in books such as Humphreys (1978).

Postemergent attacks by fungus diseases or by insect pests may seriously reduce the stand of the young pasture. Treatment against these problems may be relatively simple - Jones (1965) recommended seed treatment of Siratro (Macroptilium atropurpureum) with Dieldrin to prevent attack by bean stem maggot (Melanagromyza phaseoli) and seed dresssings may help to prevent fungal "damping off."

It is desirable to apply fertilizer to correct known deficiencies in the soil, and soil analysis and local experience are very useful guides to fertilizer treatment. In extreme conditions, complete failures of pasture seedings may result unless soil nutrient deficiencies are corrected; the coastal sandy "Wallum" soils of Queensland are a well-known example (Andrew and Bryan 1955).

Phosphatic fertilization is particularly important, especially for legume establishment, and plants with a balanced supply of nutrients may be better able to withstand stress. Souto and Dobereiner (1970) showed that seedlings of Neonotonia wightii with adequate phosphate were more heat tolerant.

Recent work at the Grasslands Research Station, Marondera, Zimbabwe, (Grant and Tanner, unpublished) indicates that several subtropical pasture legumes possess an ability to extract phosphate that would normally be considered unavailable. Therefore, in asessing soil analyses some attention should be paid to the total phosphate because legumes responded equally to a large amount applied intially as to a series of smaller dressings over several years. These remarks also applied to other species, mainly grass, which tended to show greater responses than legumes in some cases.

One of the legume species, fine-stem stylo cv. Oxley (Stylosanthes guianensis), after large initial responses to single superphosphate eventually almost disappeared in some plots, whereas Siratro (M. atropurpureum) gave continuing responses on granite sands. Stylo decline correlated significantly with decreased concentration of zinc in the herbage, and this correlated with higher phosphate level.

In the second season, stylo numbers were greatest where the soil had contained 150-160 ppm total soil phosphate, with a marked fall off either side. Zinc sulphate applied to another pasture significantly increased legume numbers.

Millikan (1962) with Subterranean clover found that critical herbage zinc levels varied according to soil phosphate. Deficiency symptoms did not relate to soil zinc, but to a high phosphate to zinc ratio. He, therefore, suggests that zinc is essential to phosphate utilization by the plant.

Other recent work at Grasslands has consistently shown responses of many subtropical pasture legumes during establishment to dolomitic lime, interacting with the level of single superphosphate application. This can be related mainly to calcium and also magnesium.

Edye et al. (1964) (quoted by Humphreys 1978) showed the marked effect of NPK fertilizers on establishment and yield of Buffel grass. Nitrogen applications to young pastures need to be carefully monitored. There is usually a release of nitrogen during soil preparation and extra nitrogen may merely cause the annual grass weeds to grow faster and smother the slow-growing perennials. Nitrogen must be used particularly carefully on pastures containing legumes.

Leslie (1965) remarked that in his experiments very little mortality of seedlings occurred more than 5 weeks after emergence. This may be so on ploughed land but in grassland reinforcement, mortality is common at much greater ages and marked differences between species may occur. These differences appear to increase as the degree of competition to which the seedlings are subjected increases. Thus, Cook and Dolby (1981) found that Buffel grass established as well as Siratro on cultivated strips but less well when sown into grassland. Differences were also observed in the time of mortality - most of the grass seedling deaths occurred during the 12 weeks after emergence whereas Siratro was more persistent over the period but suffered greater losses over the winter-spring period.

Similarly, Clatworthy (1980), comparing 12 legume strains at two sites, recorded marked differences in the survival of seedlings from the first count (6 weeks after seeding) to the last (in the following rainy season) when sown into disced grassland. On the sandy soil, only the Stylosanthes species and Siratro had survival rates greater than 25% and three strains of Desmodium species each had less than 1% survival. In contrast, on the heavier soil, where weather conditions were also more favourable, more than 25% of the seedlings of all the legume strains survived, but Stylosanthes species and Siratro again had the highest values. The selection of species or strains of high survival ability is particularly important when pasture plants are sown in adverse conditions.

PRACTICAL APPLICATIONS

(a) Scarification of seed Maximum germination is obtained with some seed damage with some hard seeds.

In the Third World countries, where control over sowing conditions is less certain, this option may be useful even for arable land. The harmless inexpensive method of natural fluctuating temperature would suit many Third World countries like Zimbabwe where germination of fine-stem stylo seed spread in the sun during the dry season increased from 10 to 40%. Acid treatment and even hot water may present practical difficulties, but some seeds can be scarified by rubbing between flat piecies of wood, and other types can be churned in an abrasively lined barrel. Criteria for commercial mechanical scarification of nearly all types of seed do exist, and where machinery is available this method is very useful for bulk quantities.

(b) Species Legume seedlings are particularly vulnerable during the 4-6 week period when developing their tap root. Particularly with species that germinate under stress, the presence of some trash or mulch will ensure that at least some of the seedlings survive subsequent dry spells.

(c) Soils that form a hard crust The seedbed should be left rough without cracks and should not be rolled. Legumes are better sown at 5 mm only, and cluster sowing helps crust penetration. It is usually better to allow the action of raindrops to cover the seed. Experimental watering every 5-6 days in combination with a thin mulch fractured the crust and increased emergence, but otherwise emergence was reduced. The variable mulching usually practiced gives fair results under most conditions, and drilling by hand or machine possesses the advantage of loose soil above the seed.

(d) Weed control If herbicide is not justified (e.g., for seed crops or valuable nurse crops) then mechanical control must be done. The weeds must germinate first and in unsuitable seasons the optimum period may pass. Expertise is needed to assess the correct moment to eliminate the weeds when they are most vulnerable.

(e) Fertilization Fertilizer recommendations for pasture establishment should include up to 500 kg/ha (preferably dolomitic) of lime and about 3 kg/ha of zinc oxide or equivalent when applying phosphate, and farmers should obtain local information on other trace element deficiencies.

Grassland Reinforcement

A major effect of burning off existing vegetation is to reduce its vigour. This should be done after soaking rains have started and the new growth has flushed. Another method is to reduce the vigour by deliberate overgrazing. The use of a plough can produce uneven seedbeds. For many peasants, the only available tool is the plough and, if so, considerable pressure should follow, perhaps with the wheel of a heavily loaded scotchcart.

Strips in the grassland are best made using units of three to four discs in pairs about 1 m apart, but can also be done with an ox cultivator. In either case, a second pass with the implement is better, and about one third of the area should be cultivated. Strips should not be less than 30-cm wide because the roots of other species below the strip may cause seedling mortality during dry spells. Seed and fertilizer can be applied mechanically by attachments to the disc unit and relate to the disturbed area. Seed may be covered either by drawing a roller or by some means of brushing behind. Remarks made under 'fertilization' apply particularly to virgin grassland. Successful reinforcement has been done on old Star grass pasture using legume mixtures but the Star grass must not have been given any nitrogen the previous season.

Open Seeding Arable Land

The degree of soil disturbance should suit the type of seed. A plough is not an ideal seedbed tool and to avoid seedbeds that are not firm, either a disc harrow or cultivator followed by drag harrow and roll is better. Where most tools are available, the best combination for small legume seeds is the Cambridge roller before seeding and a flat roller afterward.

For seeding legumes, the largest lumps of soil should have a width about twice the required depth avoiding cracks where seed can be lost. But for a seeds mixture where grass seed is usually pressed into the soil surface, the best average is to sow onto a 3-cm tilth and then cover with any type of roller. Peasant farmers are unlikely to possess a roller, but seed can be covered with a thorn brush.

The foregoing remarks apply to sands, sandy-loams, and loamy-sands if the season is not too wet. On silts and clays, special expertise is needed. The use of a roller is inadvisable and in any case seed will be covered by raindrops.

Precision drills are useful, but in the long run broadcasting the seed has proved to be as good as drilling. It has been found that spreading a seed mixture in front of tractor wheels gives results similar to drilling without the drilling problem of overcrowding seedlings. For this purpose a seedbox can be mounted on the tractor mudguard conveying the seed by wide flexible steam-hose pipes to the front of the big tractor wheels. The drive is taken from the axle using a bicycle wheel frame as a reduction gear. This method places most seed firmly at the correct depth on sandy soils if the tractor wheels have fairly new tread. On heavy soil, suitable conditions would be most unlikely and seed should be broadcast.

The peasant farmer may not be able to employ a tractor, but he could use the two wheels of a scotch-cart with perhaps two children at each side dropping a measured quantity of seed from a bottle. It would be an advantage for the scotchcart wheels to have a heavy tread, and it should also be as heavily loaded as possible.

Underseeding of Arable Crops

The provision of a nurse crop for shade has the extra advantages of better land use, saving of extra cultivation, weed control, and various moisture benefits. During the early stages of a nurse crop, there is a gradual increase in shade but demands for moisture are fairly small. The leaves of the crop also attract moisture on clear nights, which benefits seedlings establishing on the surface. This advantage continues well after the nurse crop begins to extract moisture at the deeper levels. When the nurse crop has developed a canopy it also helps to supress weeds to the advantage of undersown shade-tolerant species such as Silverleaf and P. maximum.

If weed control by herbicide is available it is possible to establish less shade-tolerant species under a thinner crop. With herbicide (Alachlor or Eptam), underseeding is best done at the time of nurse-crop emergence. For this, tractor wheel seeding is particularly useful. However, seed can be broadcast between the rows using a seed measure equivalent to two or three paces and someone to cover it up by gently brushing the soil. Application of nitrogen top dressing to a nurse crop that is to be underseeded should be timed after the legumes have produced trifoliate leaves, and never top dress just before underseeding.

Peasant farmers are unlikely to possess either the expertise or the funds for herbicide use and so cultivation by hand or with oxen will be necessary. Underseeding should still be done as early as possible while there is moisture between the rows of the crop. Peasant farmers can perhaps make up for lost time by being able to utilize unpaid family help for handweeding. It is also possible to consider seeding pasture legumes within the actual row of the crop and then to plant or seed grass between the rows after cultivation. If the undersown pasture has to compete with weeds as well as the nurse crop, poor establishment will result.

Grazing of crop residues can be done with care after the legumes have been either frosted or become dormant during the dry season, but sheep should be avoided, because they nibble close to the crown of the legumes. Grazing of crop residues should stop when the legumes send out fresh green shoots in spring and should not be resumed until there are sufficient other-species grazing to satisfy the animals.

Underseeding may lead to another weed problem in the following season. The presence of a desirable grass will help to reduce this problem, but there is always a period before the grass is fully established when broad leaf weeds will flourish. If these weeds are mown in time, pasture survival will be improved, but, because it is also a period of much farm activity, weeds may either be allowed to seed or be cut too soon. The cost of mowing is questionable unless the cut herbage can be preserved as fodder and silage making is a good gambit.

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ANIMAL EXPERIMENTS AS A MEASUREMENT OF PASTURE PRODUCTIVITY

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Abstract *Pastures in Africa are usually grazed, therefore, evaluations of pasture species and varieties must include grazing experiments. Grazing experiments are expensive and of a semipermanent nature and must, therefore, be kept as small as possible while at the same time producing accurate results. The objectives of grazing experiments must be clearly defined at the outset. Treatments should be selected to complement the local farming practice as well as to describe the productive potential of a pasture type in the environment in question. Replication of experiments is essential especially with regard to pasture persistance. Animals used in grazing trials must be carefully selected and have sufficient genetic potential to reflect pasture productivity. Objective criteria must exist for the starting and stopping of grazing trials. Measurements of the productivity of both animals and pasture should be complementary and add to existing knowledge.*

Most pastures in Africa are grazed, therefore, experiments designed to assess pasture productivity will at some stage have to use the grazing animal. The grazing experiment gives the researchers an opportunity to, at least in part, simulate producer operations. It is important that experimental conditions are such that results are readily interpreted in terms of the local farming practice. However, the desire to reproduce farm conditions should not be an end in itself, particularly in the case of low-producing peasant farming systems. Researchers should make every effort to broaden their horizons to encompass all possible alternatives and extract the greatest productivity from the resources available, including their own abilities.

The conduct of grazing trials demands a high standard of both pasture and animal husbandry. Management must be capable of meeting the demands of what is in essence an intensive farming unit, before any experimentation begins. Grazing trials are the most expensive phase of pasture evaluation in terms of land, livestock, time, and expertise. It is, therefore, essential that as much of the guesswork as possible be removed from growing the pasture in the environment in question before grazing experiments are undertaken.

Grazing trials and the results gained from them cannot be viewed in isolation from the prevailing economic situation and systems of production. Trials should, therefore, be aimed at complementing and augmenting existing production systems as well as creating new ones.

OBJECTIVES AND PLANNING

The objective of an experiment can be arrived at by first defining the problem. This is usually achieved by asking a series of simple questions. For instance, in the Zimbabwe highlands, we could well ask, does the natural grazing have sufficient quantity and quality to sustain the classes of livestock commonly in use? Can we improve on the natural situation? If so, by how much, with what inputs, in what season, and at what cost? In asking these questions the objectives of research become clearer.

A grazing trial planned for a specific purpose is of a semipermanent nature. The original plan, therefore, needs to be sound if resources and time are not to be wasted. The timely replication of experiments is essential, and grazing trials should run for at least 3 years. In environments where rainfall is low and variable, this time should be extended to cover a representative climatic period. Grazing trials demand that the researcher is responsible for land, animals, and their combined management. As is often the case, animal and pasture research persons work on the same station, and there are opportunities to combine resources. Cooperation may take the form of the pasture and animal workers using animals that are involved in experiments conducted by both scientists. This is fine so long as all parties agree on priorities beforehand.

In some circumstances it may be necessary for animals from pasture experiments to go on to a pen-finishing phase. This has little to do with pastures research, but the results of pen feeding are often of considerable importance to the profitability of the final product. It would be best if the responsibility for this phase were given to the pasture researchers.

The class of livestock used in an experiment will often be defined by the objectives of the research. However, if a pasture is to be evaluated for the first time, then it is probably best to use that class of livestock that is simplest to manage and most readily available. Starting grazed pasture evaluations in this way will allow the researcher to set the limits of the pasture before venturing into the more complex systems involving breeding animals and their progeny.

TREATMENT SELECTION

The choice of treatments will largely depend on the objectives of the experiment. The experiment will usually take the form of groups of selected animals grazing pasture at different stocking rates or where different management treatments such as fertilizer or grazing management are to be applied. The choice of experimental design can be made in consultation with biometricians.

Generally, simple, randomized block designs are the easiest to handle. The two important principles here are replication and randomization. Ideally, treatments should be replicated both in space and in time. The area covered by grazing trials can be many hectares. It is improbable that the site and soil type will be uniform over the whole area and, therefore, replication is essential. Attempting to reduce the size of experiments by using the animal as the experimental unit is undesirable as the performance of the animals in the group is not independent. In general, it would be better to split a group into two replications even if the number of individuals is small rather than rely either on one large group or on the individual animals as replications.

Stocking Rate Selection

In an experiment to compare an improved pasture with the natural grazing of the region, the stocking rates used would have to encompass those usually used on natural grazing and then a range of higher stocking rates. When starting from scratch, it will generally not be possible to identify the optimum stocking rate for a particular pasture on the first attempt. An example of this problem is provided by the initial investigations into the productivity of Silverleaf and Star grass pastures conducted at the Henderson Research Station. In 1979, when evaluations of Silverleaf and Star grass were started, the stocking rates varied from 1.5 to 3.07 steers/ha. The range now used is from 3.9-6.39/ha as shown in Table 1.

Table 2 provides an example of an experiment that uses a wide range of stocking rates in an evaluation of nitrogen-fertilized Star grass. The range of stocking rates used is comprehensive, however, it will be noticed that treatments that would obviously fail have been omitted and this has enabled the trial to be kept to a reasonable scale.

Because stocking rate is of overriding importance to the management of pastures, if only one factor can be investigated then that factor should be stocking rate. The term stocking rate is not a precise description of any single measurement and needs definition. Stocking rate is an instantaneous measure of the number of animals per unit area (Booysen 1967). The mass of the animals is not taken into account. The term stocking rate can be refined to an expression of the animal mass per hectare or Livestock Units (LU) per hectare, but this actual stocking rate is still only an instantaneous measure and has problems that will be discussed later. Expressing stocking rate as the initial stocking rate and including a description of the animals involved will prevent misunderstandings.

Grazing days per hectare or carrying capacity is another misleading term especially when a seasonal value is expressed as a daily figure. In a situation where the

Table 1. The effect of stocking rate on the livemass gains of steers grazing dryland pastures of Silverleaf and Star grass (Spear et al. 1984a).

Year	Nominal stocking (steers/ha)	Initial fasted mass (kg)	Actual initial stocking rate (kg/ha)	Livemass gain per steer (kg)	Livemass gain per hectare (kg)
1970/80	1.50	234.8	352.2	190.4	285.6
	2.05	228.9	469.3	176.6	362.2
	2.60	232.1	603.5	174.9	454.7
	3.10	233.6	724.2	146.4	453.8
1980/81	2.25	254.8	573.3	168.3	378.7
	3.07	254.8	782.2	177.0	543.4
	3.90	253.5	988.7	141.8	553.0
	4.73	255.2	1207.1	120.8	571.4
1983/84	3.90	232.2	905.6	119.6	466.4
	4.73	221.5	1047.7	114.9	543.5
	5.56	228.2	1268.8	121.8	677.2
	6.39	228.6	1460.8	86.6	553.4

Table 2. An example of treatment selection in a grazing trial evaluation of nitrogen-fertilized Star grass pastures (Parking and Boultwood 1981).

Nitrogen level (kg/ha)	Stocking rate yearling steers per hectare									
100	5	6	7	8						
200			7	8	9	10				
300					9	10	11	12		
400							11	12	13	14

number of animals per hectare is fixed and these animals are gaining mass, the actual daily carrying capacity increases with time and a mean value could lead to an overestimate of the initial carrying capacity. Describing experiments as having been stocked with X number of animals of mass A on a certain date with the animals gaining Y kg in a given number of days and being removed from the experiment at mass B gives the reader little excuse for misunderstanding the data.

For the purpose of statistical analysis, biometricians prefer the increments between stocking rates to be evenly spaced. If the mean mass of groups is equal, this procedure is easily accomplished. However, the mean group mass between years is unlikely to be identical and comparisons between years will become invalid. This is a good reason to ensure that treatments are replicated in any one season as well as in time.

A good example of the problems associated with expressing stocking rate accurately is provided by the following experiment conducted at Henderson. To assess their compensatory growth on pasture, steers were fed four levels of winter supplement such that at turn-out onto pasture the differences in the mass of each group were significant. The groups were then each split into four stocking rates of 7, 9, 11, and 13 steers/ha and placed on nitrogen-fertilized Star grass pasture.

Obviously, because the different supplement groups had significantly different initial masses, the actual stocking rate on pasture would also be different even if the nominal stocking rates were the same. In this experiment, those steers that received less supplement during winter gained more in summer and if the stocking rate anomally were ignored this improved gain can be ascribed to compensatory growth. However, if the actual stocking rates are taken into account a large proportion of the increased gain of the low-supplement groups can be accounted for by a real reduction in stocking rate. In this experiment, the situation also arose where at the same actual stocking rate there were different numbers of animals. The treatment that contained the greatest number of animals produced greater gains per hectare. This phenomenon is more likely to be explained by compensatory growth. In this instance, the numerous lighter animals still needed extensive pen fattening, which nullified the advantage of their better growth during summer (Spear et al.1984b).

Other factors such as grazing management, fertilizer levels, and season of use also affect productivity and can be included as treatment variables. Ideally, soil fertility problems should have been corrected before the grazing trial stage is reached, however, the grazing animal does alter the relation between pasture growth and applied fertilizer because of the considerable nutrient cycling that takes place, particularly with regard to P and K. Therefore, it may be necessary to evaluate fertilizer treatments at optimum stocking rates.

Season of Use

The season of use is something that will be determined by the peculiarities and the needs of the environment in question. In the Zimbabwe highlands, the season is conveniently split into the growing season or summer and the dry or winter season. As a result of this, most pastures developed so far have been aimed at summer use only. This has made the defining of the season of use very easy in our case. In regions without frost and with year-round rainfall, deciding on the season of use will be more complicated. Experiments designed to assess year-round productivity will place different emphasis on treatment variables such as stocking rates and supplementation.

To give an example, at Henderson, Silverleaf, and Star grass pastures are used in the growing season primarily because this is the season that the farmer will derive the greatest benefit from the pasture. Now that Silverleaf pastures have set the standard, new pastures have to either do better in the growing season or provide improved pasture during that part of the year when Silverleaf cannot compete. For example Leucaena leucocephala is being evaluated primarily as an out-of-season pasture to complement the already productive summer pasture.

Specific nutritional deficiencies in pastures such as occur in Star grass pastures (Herrington et al 1971), or other deficiencies of phosphorous and sodium should be identified before the start of full-scale grazing trials. This type of deficiency is usually effectively overcome by feeding mineral supplements to animals on pasture. Problems associated with toxicity such as occur in leucaena provide more of a management problem, but can be overcome in numerous ways (Jones and Megarrity 1983). This type of problem should play little role in the selection of treatments, and if deficiencies and toxicities are a hinderance to animal production then the pastures are not ready for grazing trials.

Grazing System

The system of grazing management used is a controversial topic and many varied systems have been tried. Common sense tells us that with all the problems of variability in animals and pasture, the simplest system would be the one least likely to confound results and, therefore, the most desirable. This is represented by the continuous graze/set stock design where a set number of animals graze a single paddock without interruption for the entire period of the experiment. Under certain circumstances, continuous grazing may not be possible as in the case of leucaena in Australia (Jones and Bray 1982). In this case, a simple rotation was found to maintain pasture vigour. The problem with rotations is the infinite number of combinations of paddock numbers, period of stay, and period of absence. Rotations do sometimes have the effect of lengthening the season of use, which may be an important consideration, and, of course, if the researcher is confronted with variable experimental sites either because of slope, aspect, waterlogging, etc., splitting the areas up and spreading them among treatments by using a rotation may be a way of overcoming the problem. Again, a set stock design where the number of animals per treatment does not change is desirable.

Variable stocking rates and put-and-take systems may yield volumes of fascinating data, but they are unrealistic and difficult to interpret. This type of trial also demands high levels of management, plus the ability to make numerous decisions on when to put animals in and out of experiments. Where the limitations on research are more likely to be imposed by management than by a shortage of land or animals, every effort should be made to keep things simple and as close to reality as possible. Whatever the system chosen to evaluate pastures, the same system must be used on all the pastures in the comparisons even if these comparisons take place in different seasons. Remember that in comparison with a farmers' pastures, those on a research station will probably be treated leniently and only pastures able to stand up to severe treatments on research stations will be able to survive on the farm.

Supplementary Feeding

Once the basic information on stocking rates and animal performance has been acquired then it may be desirable to impose treatments that involve different levels of supplement, both protein and energy, in conjunction with the standard stocking rates. Whenever supplements are fed it is essential to have control levels of zero supplement. If this is impossible, as the stocking rates needed are so high or the supplement is a large portion of the animals diet, then the pasture has really become the supplement and should be regarded as such. The zero supplement treatment is the only way to provide a base line against which supplements can be compared. The data in Table 3 provide an example of the importance of the zero supplement level.

Looking at the results individually it is clear that the supplements were effective in boosting the livemass gains of the steers. However, when the performance of supplemented steers is compared to that of unsupplemented steers it is also clear that the efficiency with which the maize is used is low. This indicates that the supplement is not complementing the steer's nutrition but is acting more as a substitute. However, even

Table 3. The effect of stocking rate and level of whole maizes supplementation on the livemass gains of steers grazing dryland pastures of Silverleaf and Star grass (Spear and Chikumba 1984a).

Stocking rate (steers/ha)	Kg maize/ steer/day	Livemass gain /steer (kg)	Livemass gain /ha (kg)	Maize/steer (kg)	Consumed/ extra kg gain
3.90	0	119.6	466.4	0	0.00
	1	161.0	627.9	175	4.23
	3	169.0	659.1	525	10.63
4.73	0	114.9	543.5	0	0.00
	1	135.0	638.6	168	8.40
	3	153.0	727.5	504	13.23
5.56	0	121.8	677.2	0	0.00
	1	115.2	640.5	165	(165.00)
	3	152.8	849.6	501	16.20
6.39	0	86.6	553.4	0	0.00
	1	103.6	662.0	154	9.10
	3	136.0	869.0	504	10.20

inefficient use of a supplement does not automatically render the product of the treatment uneconomical. This example underlines the need to evaluate the whole system of production in terms of the profitability of the final product.

ANIMAL SELECTION

In any grazing trial the animal and its correct selection is of prime importance. The objectives of the experiment will pinpoint the class of animal that is required and the measurements of production, i.e., meat, milk, or progeny that are needed. Whatever the class of animal chosen, the researcher must attempt to either neutralize or standardize the effects of disease and parasites to reduce any additional variation. It is very important that prophylactic treatments are correct and constant through the years of the experiment as variation in tick challenges, for instance, could confound results. The procedures adopted will vary from region to region and veterinarians are best qualified to advise on this matter. For example, at Henderson all experimental animals are dipped weekly during summer and fortnightly during winter. The brand of dip is changed for the different seasons and all animals are dosed with antihelminthics at the beginning of any particular phase, e.g., the start of the summer pasture phase, the start of winter, or before entering pens. This procedure is strictly adhered to as experience has shown that failure to do so can result in disaster.

Environmental Adaptation

Animals selected for inclusion into grazing trials must be adapted to the environment and have the potential to respond over the applied range of treatments. If the environment is improved by the introduction of pasture legumes then improved animals that areadapted to this new environment must be used. This is particularly so in the case of high-quality pastures where production per head is at a premium. If the potential of the animal limits production then the pasture cannot be fully evaluated. An example of this problem can again be provided by experiments conducted at Henderson. The evaluation of Silverleaf and Star grass has already been mentioned. Within each experimental group of steers on the pasture the variation in total gain per head is generally considerable. In the 1983/84 season, two groups of steers were specially selected on uniformity and previous performance before the usual group selection and then placed in the trial as duplicate treatments of normally selected steer groups.

Table 4 shows that the specially selected steers gained more than the normally selected steers. This example illustrates the necessity of using uniformly high potential animals when evaluating highly productive legume pastures. When the evaluation of Silverleaf and Star grass was extended to beef cows and calves a further problem of animal potential arose. At stocking rates equivalent to those used by steers, indigenous beef cows became overfat and failed to reconceive at all.

There are two problems in this respect: (a) the cows used are not capable of converting the pasture into calf gain efficiently, and (b) the trial lacks

Table 4. The effect of steer selection on the live mass gains of steers grazing dryland pastures of Silverleaf desmodium and Star grass at different stocking rates (Spear and Chikumba 1984b).

Stocking rate (steers/ha)	Initial mass fasted (kg)	Final mass fasted (kg)	Gain livemass per steer (kg)	Gain per hectare (kg)
3.90 normal selection	232.2	351.8	119.6	466.4
3.90 special selection	227.6	387.6	160.0	624.0
4.73 normal selection	221.5	336.4	114.9	543.5
4.73 special selection	227.8	370.0	142.2	672.6

repeatability as the cows are not repeat calvers. The solution to the first problem would be to use a breed with a higher potential and the second problem would best be solved by using fewer treatments with larger groups.

Table 5 shows clearly that steers are more efficient than cows at present and this fact emphasizes the need to evaluate pasture with a range of livestock types as the results of one class are not readily extrapolated to another. As a result of the problems with beef cows on pasture, dairy cows are now being used to obtain a direct measure of production through milk yield. These cows were selected for low milk yield and preliminary results indicate we may have again fallen into the same trap and selected cows with too little potential. These examples show that the initial investigations into a pasture's potential may be time consuming but once the foundations have been laid further comparisons should be straightforward.

Selecting animals for inclusion in a group and the allocation of groups to treatments should be completely random. However, if group size is small and the variation in the animals is large, a form of stratified selection will give groups a more representative composition. The allocation of selected groups to treatments, however, must be completely random and final. The selection of animals for experiments can be done on sex, age, mass, breed, uniformity, and previous performance. As has been mentioned, steers are the easiest of cattle to work with and these can be selected on breed, age, and mass. At Henderson, narrow limits are set, and, in any given experiment, the difference between heaviest to lightest must be less than 50 kg and the breed variability is reduced by purchasing steers from the same producer each year. Off-type or defective animals, that is animals with opthalmia, incomplete castrations, or other disorders, must be rejected at the start.

Beef Cow Selection

The selection of cows is a far more difficult procedure unless accurate records of their history exist. When records are available then random selection of small groups should be replaced by stratified sampling. Groups should be selected to have had the

Table 5. A comparison of the effect of stocking rate on the livemass gains of cows and their calves and steers grazing dryland pastures of Silverleaf desmodium and Star grass in a four-paddock rotation (Spear and Chikumba 1984c).

Stocking rate cows + calves /ha	Initial fasted mass/ha (kg)	Livemass gain/ha (kg)	Stocking rate (steers/ha)	Initial fasted mass/ha (kg)	Livemass gain/ha (kg)
1.00			2.25	517.3	366.8
Cows		120.3			
Calves		165.7			
Total	386.7	286.0			
1.50			3.07	705.1	518.8
Cows		168.3			
Calves		229.5			
Total	558.8	397.8			
2.00			3.90	897.3	609.6
Cows		170.7			
Calves		292.7			
Total	799.4	463.4			
2.50			4.73	1092.3	641.9
Cows		162.5			
Calves		326.5			
Total	996.9	489.0			

same number of lactations in an equal number of years. The previous season is of major importance because a cow that was dry last year will produce a heavier calf than if it had been lactating. Ideally, the same cows should be used year after year especially where fertility and calving dates may be affected by treatments. The ratio of male to female calves will always confuse the differences between groups especially when the herd is fixed; appropriate adjustments are suggested in a review by Mannetje et al. (1976).

Variability in calf performance is also a function of the sire. Artificial insemination has the advantage of giving the researcher an opportunity to standardize sire effects. Cows in grazing experiments should only be inseminated on natural oestrus as synchronization may interfere with treatment effects. If bulls are to be used then these should preferably be siblings or have similar proven records. The breeding period must be limited and uniform over all treatments, at Henderson 60 days of natural service is allowed. Periods of longer than 90 days allow a large spread in calving date, thus making adjustments for age necessary when calculating weaning mass. This type of adjustment can only add to variability, therefore, long breeding periods are undesirable. If natural service is to be used on small experimental groups then the bull will add to the stocking rate and this addition will not be uniform at all treatments.

Experiments using breeding cows are easily disrupted by disease, such as contagious abortion, and extra care in selecting and purchasing animals is needed to ensure that these problems do not occur. If the progeny of the experiment are to be used in further experimentation as in systems trials such as those in operation at the Grasslands Research Station (Grant and Golding 1973), then the breeding herd must be of a size sufficient to ensure that enough progeny are available each year for the various subsequent trials.

Dairy Cow Selection

The selection of dairy cows for grazing trials takes the same form as that for beef cows, but is even more critical, especially in areas such as Zimbabwe where milk production from pasture is not common practice or where improved pastures are a challenge to the potential of the traditional dairy animal. Grouping cows on previous lactation yields and the number of days into the current lactation will be the most powerful way of balancing treatment groups. Another problem to be overcome is that of the season of production. Even if the pasture to be assessed is to be grazed all year round with or without supplements some form of control must be placed on the season of calving both to make comparative study easier and to optimize production. In Zimbabwe, where the grazing season under dryland conditions is clearcut, the season of production, based on pasture, is similarly defined. To evaluate fully the potential of the pasture, the cows should be in the first 100 days of their lactation at the onset of grazing. Cows must have the capability to produce in excess of the pasture's potential. This is essential so that accurate estimates of pasture productivity are made before experiments involving supplementary feeding are started.

A criticism of milk production from pasture when the pasture makes up only part of the season is that there may be carryover effects from previous feeding regimes and that cows may be "milking off their backs." The keeping of accurate records of yield and body mass particularly during periods of transition from one feeding regime to the next will largely dispel idle speculation on the true value of the pasture.

IDENTIFICATION

Before an experiment can begin it must be possible to record accurately the performance of an individual animal and this requires the animal to be identifiable. Some form of permanent marking is essential. Branding, freeze or fire, is one alternative and is useful for animals that will occur in trials year after year such as cows. The use of ear notching or ear tags is common and if done correctly animals will be easily distinguishable into groups at a distance.

At Henderson, the procedure is to tag each animal on arrival at the Station with a small numbered metal tag. Once the animal has been selected for a particular group then an additional tag, this time a coloured and numbered plastic one, is applied. The combination of colour and numbers and letters should identify the animal as a member of a treatment group and as an individual. Painting group numbers on the cattle with branding irons is an appropriate solution if tags should fade or fall out and of course the metal tag remains as the safeguard. Accurate tagging during critical periods such as calving is essential and mistakes at times like these are difficult to rectify.

MANAGEMENT DECISIONS

Definite criteria are needed for starting and stopping the phases of a pasture evaluation. If the experiment involves year-round grazing then this problem is eased. However, if the pastures to be evaluated comprise only part of the season then objective means must be found to describe when the pasture is ready for grazing and when the animals should be removed.

The time of stocking can be related to the amount of herbage available per hectare or per unit livemass of the animals to be stocked. The amount of herbage may be refined into the important components such as legume content, especially if the amount of legume is closely related to animal productivity, or sensitive to overgrazing. Ideally, the amount of herbage per unit mass of animal should be used because a flat rate of so many kilograms per hectare will favour treatments with lower stocking rates. The situation is confounded when rotations are used, for example: if paddock no. 1 in a four paddock system is stocked on the correct date then forages in paddock no. 4 will be mature by the time it is first grazed. Experienced managers are rarely wrong in their estimates of when a pasture is ready for grazing, all that is needed is to quantify the manager's decisions. In systems trials or where a pasture is to be used or sacrificed to fill a specific need, such as Eragrostis curvula pastures for spring grazing, then stocking can be done by dates as the subsequent performance of the pasture is less important than its aseasonal contribution.

When to remove animals also depends on the objective of the experiment. If the productivity of the pasture is of prime importance then the animals should be allowed to gain mass or produce milk for as long as possible. Steers at Henderson are removed from experiments when the mean group mass declines at two consecutive weekly weighings. If the steers are to go on to a fattening phase this should occur immediately, however, if not, then the animals should be slaughtered as soon as possible. Beef cows and calves are removed from pastures when either the mean group mass of the cows and/or calves declines at two consecutive weekly weighings or the mean group cow mass is 95% of the summer peak. The loss of cow mass criteria is arbitrary, however, in beef trials the calf gains are of prime importance while cow mass is only of interest if it is so extreme as to interfere with reproduction. At the end of summer, it is possible for calves to continue gaining when their dams are losing mass. A compromise is, therefore, needed, and the above mentioned critieria should be implemented. In practice, the system works well; once the cows have lost 5% of peak mass their calves generally start losing mass as well.

Dairy animals pose a special problem in that any depression of their daily yield is not easily recouped at a later date. If later performance is not of interest then the cows can remain on the pasture as long as they produce and do not lose mass. For instance, cows that produce less than a total of 20 L in 5 consecutive days and any cows losing mass can be removed from the pasture on an individual basis.

When animals are to move from one pasture to another, as the seasons change, as part of a production system, then the results of individual pasture evaluations carried out beforehand should provide the necessary guide to management decisions.

ANIMAL MEASUREMENTS

The frequency and type of measurements that are taken depend on the resources available and the data required. Mass changes are the most commonly recorded measurement, but measurements of fertility and milk production are also important. In dairies it should be possible to obtain daily individual production data. Cow mass must not be overlooked and monthly weighing should be the minimum. Other measurements depend on the object of the experiment and those factors that are financially important. In Zimbabwe, for example, the producer price of milk per litre is partly controlled by the butterfat percentage and the quality of the milk. Therefore, monthly estimates of the butterfat percentage and bacterial counts are essential. Other measurements will only be made if specifically required.

Body Mass Changes

Recording mass changes in all classes of animals is an accurate way of monitoring productivity. However, animal mass is subject to considerable variation due in part to the gut-fill of the animals. Fasting animals for 16-24 hours before weighing reduces the variability in weighed mass by reducing the gut-fill of the animals. Fasted masses are obtained only when accurate measurements are needed, i.e., at the start and end of a phase of the experiment. Routine weighings during the course of the experiment are needed for trend analysis but need not be as accurate. These weighings are best done as rapidly as possible to minimize animal stress. The correction of weaning mass for the date of birth is a procedure that is often used, however, if the date of calving is a treatment effect, any adjustment will only confound the results. When the pasture experiment only makes up part of the season or preweaning period then calf gain would be more appropriate than weaning mass as a measure of production.

The most accurate way to estimate animal gains is to measure actual carcass mass changes. This can be done by killing samples of the experimental animals at strategic times during the experiment. All beef animals at Henderson are weighed fortnightly and weekly toward critical changeover periods at the end of a phase. At the changeover, all animals are fasted and the fasted mass at the beginning and end of the phase is used to estimate the gains. If the animals do not progress to another phase or are members of a slaughter control group then they are slaughtered as soon as possible. The data at this stage are represented by carcass mass or cold dressed mass (hot dressed mass minus 3%). In Zimbabwe, the slaughtering is performed by the Cold Storage Commission, a parastatal organization responsible for the purchase, slaughter, and distribution of beef. The carcasses are graded according to sex, age, the mass-to-length ratio of the carcass plus the fat cover. All this data can be condensed to a value per kilogram or per carcass. The pricing varies from a peak in January to the lowest price in May. The time of slaughter is often a treatment effect and, thus, so are price changes.

PASTURE MEASUREMENTS

Pasture measurements will help explain trends in animal performance and should be designed to monitor those aspects of the pasture most likely to influence animal productivity. Pastures can be measured for yield, quality, composition, and persistence. Researchers must decide which component is most important in their particular circumstance.

Measurements of the quantity of herbage on offer and pasture yield are both only indirect measurements of the value of the pasture to the animal as neither gives an indication of what the animal is eating. The quality of the pasture can be estimated by digestibility trials, however, unless fistulated animals are used it is very difficult to be sure of the animal's diet. Given a choice of legume and grass in a pasture, steers may display "nutritional wisdom" and select a diet that meets their requirements instead of eating representative samples of each component of the pasture (Mufandaedza 1980).

Measurements of the composition of the pasture are particularly important in grass-legume or multispecies pastures where the percentage composition of the legume, for instance, has close relation to animal performance. Changes in the botanical composition of the pasture are often not immediately reflected in animal performance. The interaction of the grazing animal and the composition of the pasture must be recorded especially with regard to weed invasion and pasture persistence.

Persistence measurements of principal pasture components are essential and are best done over a long period of time. Botanical measurements in general are sensitive to climatic fluctuations, particularly rainfall. Therefore, in drier climates, botanical analysis must cover a representative climatic period. In conjunction with these botanical measurements, and especially when fertilizers are applied as treatment variables, routine soil analysis should be standard practice.

FACILITIES

Well designed and maintained facilities are vital to the success of grazing experiments. The aim of the handling facilities should be to carry out whatever procedures and make whatever recordings the experiment requires with the least possible stress to the animals. The facilities should include animal handling equipment, water reticulation, and adequate paddocking and herding corridors. Ideally, the handling facilities should be centrally located with a plunge dip or spray race, a scale suitable to the class of livestock to be handled, and holding facilities sufficient to accommodate the majority, if not all, of the experimental groups at one time without any mixing.

The construction of the facilities must be such that animals are unable to escape, this is particularly important when weaning or fasting is carried out. At least some of the holding pens should have water in case animals are confined for long periods of time or in extreme heat. The scale neck clamp, race, and recording desk should all be under shelter and on a concrete floor. Some form of illumination and running water are essential at the facility particularly if artificial insemination is to be undertaken. The actual design and layout of the facilities is a subject that requires considerable planning if the handling of livestock is to be carried out efficiently.

All experimental paddocks should be constructed to ensure animals are confined to the area designated to them. Each paddock must have a reliable water source and the water reticulation system must be able to sustain the experiment even in times of drought.

CONCLUSION

Grazing trials are usually the final stage in pasture evaluation, thus the results of the experiments will probably decide the fate of the pasture in the region in question. For this reason the experiments need to be carefully planned, fastidiously conducted and interpreted without bias.

The objectives of the research program must be clear from the start. Treatment and animal selection must be such that no aspect of production is ignored and the full potential of the pasture is accurately described.

Well-designed experiments and comparisons will yield conclusive results that leave the application of the findings beyond doubt. The development of systems of production, based on these results, that use the natural resources efficiently and at the same time increase the viability of the farmer must be high on the list of research priorities.

If the final product of a pasture evaluation program is a lucid publication containing comprehensive information on pasture utilization, productivity, and management then the researchers will have made a significant contribution to agricultural development in their regions.

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COMMERCIAL SEED INCREASE OF NEW PASTURE CULTIVARS: ORGANIZATION AND PRACTICE

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Abstract *Pasture seed production technology is reviewed in the context of commercial increase following the release of a new cultivar. Particular emphasis is placed on the organization and location of production, crop establishment and management, harvesting, and the role of research with brief notes on drying, processing, packaging, storage, seed testing, and seed certification.*

Seed production is a crucial step in the commercialization of newly released pasture plants. Most improved pastures are established from seed. Unless this necessary seed is produced, the final step of widespread commercial sowings with the new cultivar cannot take place and all the preceding work of plant introduction and evaluation before release will have been wasted.

The strategic importance of seed production is far greater than its immediate economic value. This was recognized in Queensland during the late 60s when lack of seed prevented the commercial use of a number of new grasses and legumes developed during the so-called tropical pasture revolution. This problem has since been largely overcome in Queensland, but the scenario could be repeated in the future as new cultivars are developed and released in other countries such as those of eastern and southern Africa represented at this meeting. The application of pasture seed production technology to the multiplication of commercial seed supplies after release is therefore the subject of this paper.

MECHANIZATION

It is neither necessary nor desirable for pasture seed production to be highly mechanized where labour is both abundant and cheap. However, the degree of mechanization required is an internal decision for each country and must be made in the light of prevailing social and economic factors.

Pasture seed production in the countries represented at this workshop is likely to rely on a substantial labour component in the foreseeable future unless suitable machinery for use with arable field crops is already available in some situations. In time, this emphasis may change in response to social and economic trends such as occurred in Queensland 30-50 years ago when farmers were forced into mechanization by the increasing cost and scarcity of suitable labour. Machinery, however, is expensive and the cost is usually spread over other crops in mixed enterprises, or over even larger crop areas by contractors.

At the same time, mechanization may be inevitable in some situations: for example, mechanical harvesting of crops such as Greenleaf and Silverleaf desmodium (Desmodium intortum, D. unicinatum) and the tropical stylo cultivars (Stylosanthes guianensis var. guianensis) may be the only means by which large quantities of seed can be produced. Again, however, this is an internal decision to be made by each country in the light of local conditions.

LEVEL OF TECHNOLOGY

Intensive seed production with high levels of technological input is not necessarily the most cost-effective approach, particularly with grasses that flower strongly throughout the growing season enabling seed to be produced under less elaborate systems. For example, large quantities of seed are produced from buffel grass (Cenchrus ciliaris), Pioneer Rhodes grass (Chloris gayana), and green and Gatton panics (Panicum maximum) by opportunist harvesting of pastures in central Queensland; paddocks are shut up for seed production after good rains in late spring or early summer and crops generally receive little deliberate management beyond shutting the paddock gate (Loch 1983a). However, a much higher level of input is required in other cases, particularly shy-seeding cultivars such as Narok setaria (Setaria sphacelata var. sericea) or grasses with restricted flowering periods (e.g., Callide and Samford Rhodes grass).

The wide range of available grasses and legumes together with social differences have resulted in a multiplicity of seed production systems such as those described for Latin America by Ferguson (1979). Intensive systems, however, generally give higher yields and more consistent production than opportunist ones and should therefore be adopted with new cultivars, at least until adequate supplies of seed are available commercially. In Queensland, the trend in recent years has been to restrict first-stage seed increase where possible to the best and most conscientious growers with a proven record, and access to supplementary irrigation is almost mandatory. These precautions reduce the risk of losing the small and valuable nucleus of seed that is available at the time of release. They also maximize the multiplication factor so that full-scale commercial seed production, possibly based on a less elaborate system, can be undertaken as soon as possible after release.

Intensive systems do not necessarily imply mechanization. Instead, a careful rather than a casual approach is intended with plants being established and managed primarily as seed crops. With this approach in mind, appropriate systems with a substantial labour input will no doubt evolve in response to different social structures and pressures in various countries.

ORGANIZATION OF SEED INCREASE

Since the early 70s, the initial multiplication of commercial seed supplies for each new cultivar in Queensland has been organized by a separate and autonomous Seed Increase Committee (SIC), the operations of which are described by Hopkinson (1980). Each SIC consists of a chairman from the Queensland Department of Primary Industries (QDPI), one representative each from the Seed Industry Association of Australia (the merchants) and the Queensland Seed Producers' Association, and a member appointed by the Queensland

Herbage Plant Liaison Committee that makes the decision to release each new cultivar. In recent years, SICs have tended to operate on a statewide level in contrast to the more parochial district basis of earlier Committees. All necessary arrangements, including selection of growers and pricing and distribution of seed, are made through the SIC until it decides to disband when adequate commercial supplies of seed are available.

Before the 70s, each new cultivar tended to be released and almost immediately forgotten by official bodies whose task had been completed. The main impact of the SIC system has been to maintain official interest beyond the point of release until the new cultivar has in fact been launched commercially. This particular system, however, need not necessarily be adopted in other countries provided the new cultivar receives the required impetus after release from other sources. In Queensland, for example, the successful commercial increase of Callide and Samford Rhodes grass (two of the forgotten cultivars from the 60s) and of Hatch creeping bluegrass (Bothriochloa insculpta) was recently coordinated without formal SICs.

Commercial seed increase is extremely vulnerable in the early stages because of the restricted scope of production and limited experience with the new crop. The overall risk of failure can be reduced by carefully selecting a minimum of three to four experienced seed growers each with a reasonable-sized area; if possible, production should also be spread geographically into different districts to minimize the impact of natural disasters (e.g., prolonged drought, unusually heavy frosts, and rain and wind at harvest). With a small nucleus of seed (50-100 kg or less), the SIC is restricted to a "bulk-up" year involving a few selected growers; when larger quantities of seed have been produced, they can then advertise for wider applications for new seed areas. With larger quantities of seed at release (100-200 kg or more), the SIC is able to call immediately for wider applications from a larger number of growers (usually more than 10).

Despite the best laid plans, individual areas may fail and it is not uncommon to produce little or no seed until at least the 2nd year after release, particularly with the slower-establishing, longer-lived perennials.

Hopefully, however, there will be one or more notable successes on which future multiplication can be based. Over a period of years, it has also been possible to identify the most consistent growers for first-stage seed increase, thereby increasing the chances of success with future releases.

Seed prices during the initial stages of multiplication are set by the SIC bearing in mind the effects of supply and demand. These are generally lower than could be expected in an unrestrained market, but higher than likely long-term values. Although relatively high seed prices for a new cultivar are often decried, this attitude is unrealistic and ignores the accompanying benefits. First, these prices provide entrepreneurial returns to successful first-stage growers who contribute greatly to our overall experience with the new crop. Second, they are a necessary catalyst to attract new growers, leading to full-scale commercial production and lower prices as soon as possible after release. Third, they enhance market development by spreading limited supplies of seed over a larger number of consumers, not just a few big orders.

Publicity for the new cultivar should coincide with the availability of adequate supplies of seed, not with the earlier date of release. Otherwise, farmers will simply lose interest in hearing about what they cannot buy. Publicity at this stage is also incumbent on the institutions that developed the new cultivar if they hope to keep faith with the growers who have taken the necessary risks in producing the required seed. Very recently, there have been moves to include the coordination of publicity among the duties of the SIC.

LOCATION OF SEED CROPS

The choice of a suitable locality or localities for seed production has been strongly emphasized in the past (e.g., Hopkinson and Reid 1979; Loch 1980) and should be the first consideration with seed production in a new country. Biologically, the location of seed crops depends primarily on climatic factors and to a lesser extent on soils. In practice, it also depends on other factors such as the availability of machinery and associated services, farmer expertise, and historical reasons; however, these are perhaps of less relevance to African conditions.

Climate

The legumes and grasses sown for pasture use in the tropics and subtopics comprise a diverse group adapted to a wide range of different environmental conditions. As a result, no single environment can be regarded as the best for growing seed crops of all of these. Seed production of individual cultivars tend to gravitate toward different districts according to their general adaptation. In addition, a larger number of cultivars can be grown in districts with a greater amount of climatic diversity, simply because suitable niches can be found for each one. On the Atherton Tablelands of north Queensland, for example, there is a steady gradation from a hot monsoonal climate on the lower northern end (Walkamin-Mareeba) through to a cooler, moister, higher-altitude environment in the Atherton-Kairi-Tolga area; this is accompanied by a change from crops such as siratro (Macroptilium atropurpureum), stylo, Caribbean stylo (Stylosanthes hamata), shrubby stylo (Stylosanthes scabra, and sabi grass (Urochloa mosambicensis) at the northern end to others such as Greenleaf desmodium, glycine (Neonotonia wightii), Kenya white clover (Trifolium semipilosum), green and Gatton panics, Rhodes grass, and setaria on the higher parts.

Tropical Legumes

The climatic requirements of the more uncompromisingly tropical legumes have been discussed in detail by Hopkinson and Reid (1979). Most show some kind of short-day response and require sufficient seasonal variation in daylength to give clearly defined phases of vegetative and reproductive development for a heavy seed crop; however, this must be balanced by frost-free conditions because of their winter-flowering behaviour. With siratro and centro (Centrosema pubescens), in particular, an element of stress (most conveniently from soil moisture) is necessary to promote vigorous reproductive growth, hence the need for a climate with reliable and well-defined wet and dry seasons. This is also an advantage with Malawi glycine because it will flower strongly and set little seed unless further vegetative growth is curtailed by drought during flowering. A 4-month wet season appears adequate for the vegetative growth of most tropical legumes, with a lower limit of about 800 mm average annual rainfall (AAR) to provide sufficient soil moisture, and an arbitrary upper limit of 2,000 mm to avoid excessively wet conditions for crop management operations and to reduce the risks of disease.

Within those general requirements, there are specific preferences for particular crops. Centro, puero (*Pueraria phaseoloides*), and calopo (*Calopogonium muconoides*) require warmer winters than most other species. Siratro performs best under a fairly short wet season and with a winter climate modified by irrigations (Hopkinson 1977). Glycine, axillaris (*Macrotyloma axillare*), and the desmodiums prefer a more prolonged wet season and rather cooler conditions than other winter-flowering species, hence the location of seed crops in the warmer lowland subtropics or in elevated tropical districts with some frost risk.

Diseases may also influence the final choice of site for seed production, although the use of fungicide is sometimes justifiable. With siratro, Rhizoctonia largely prevents seed production in wetter areas, and bean rust has increased difficulties in marginally cool districts. In the case of *Stylosanthes* species, botrytis head blight and, more recently, anthracnose have imposed serious restrictions on seed production in some areas.

Subtropical Legumes

There is a further heterogeneous group of legumes that are grown for seed under subtropical conditions in Queensland. Essentially, these legumes are adapted to subtropical temperature regimes; most escape frost because of their flowering behaviour; and stress has little or no apparent effect of stimulating flowering. Kenya white clover (which is also grown at higher elevations in the tropics) flowers during winter and early spring, but is generally unaffected by anything other than the heaviest frosts in the moist subtropics. Lotononis (*Lotononis bainesii*) flowers mainly during spring. Fine-stem stylo (*S. guianensis* var. *intermedia*) flowers strongly during summer and early autumn due to an apparent quantitative long-day requirement (Cameron and Mannetje 1977). Bargoo jointvetch (Aeschynomene falcata) and Wynn roundleaf cassia (Cassia rotundifolia) appear insensitive to daylength and can flower throughout the growing season provided there is adequate soil moisture. The newly released American jointvetch (Aeschynomene americana) cultivar Glenn also has some prospect of seed production in subtropical coastal districts because its late autumn flowering behaviour allows sufficient time for a seed crop before frosts are likely; however, it may be restricted to relatively warm sites to minimize the risk of botrytis head blight through longer periods of dew on heavy crops as nights become cooler. A similar cultivar of American jointvetch is already grown for seed under subtropical conditions in Florida.

The various subtropical legumes need a period of favourable growing conditions to establish the framework on which the harvested crop is produced, although this is generally shorter than the 4 months suggested earlier for tropical species. The wider distribution of rainfall in the subtropics allows this to be done earlier in the growing season (e.g., fine-stem stylo) or during late winter (e.g., lotononis). Where crops mature during summer, this also tends to reduce the incidence of disease during flowering and the risk of wet weather interfering with harvest.

Because of the more erratic rainfall in the subtropics, supplementary irrigation improves the reliability of cropping and increases seed yields. This is of particular importance in lower rainfall districts (e.g., fine-stem stylo) and with lotononis and Kenya white clover because adequate soil moisture is required during winter and early spring when rainfall tends to be at its lowest and most erratic.

Grasses

In Queensland, rainfall is the basic determinant of the distribution of grass seed crops depending on their general adaptation and daylength response (Loch 1980). Three broad groups are recognized:

(a) Buffel grass, Pioneer Rhodes grass, makarikari grass (Panicum coloratum var. makarikariense), and green and Gatton panics grow well under drier inland conditions, flower throughout the growing season, and will seed freely without special management. The bulk of seed is therefore produced by opportunist harvesting of pastures under about 700 mm AAR in the drier parts of their range in southern and (particularly) central Queensland where advantage can be taken of locally available machinery and naturally fertile soils in recently cleared areas. Inverell purple pigeon grass (Setaria porphyrantha) has similar attributes and is likely to come into this category in the future.

(b) Grasses in the second group also grow well in pastures in drier areas, but are short-day plants that, as seed crops, require moisture during the restricted periods when inflorescences emerge strongly. Seed production is therefore best in the wetter parts of their adaptive range where rain-grown crops have a greater chance of receiving adequate moisture late in the growing season during flowering and seeding, and where there is less risk of low-temperature damage to crops maturing in late autumn. For these reasons, supplementary irrigation is also an advantage. In Queensland, Callide and Samford Rhodes are major examples of this group: seed crops are now grown successfully in higher rainfall areas (generally 1,000-1,200 mm AAR) after earlier failing in drier districts where most Pioneer Rhodes seed is produced. Other examples include creeping bluegrass, late flowering strains of Indian bluegrass (Bothriochloa pertusa), and gamba grass (Andropogon gayanus).

(c) The third, rather heterogeneous group includes grasses such as signal (Brachiaria decumbens), para (Brachiaria mutica), guinea (P. maximum), paspalum (Paspalum dilatatum), plicatulum (Paspalum plicatulum), and setaria. Unlike the first two groups, these grasses do not grow strongly under drier inland conditions and, regardless of daylength response, seed is produced in the higher rainfall districts (c. 1,000 mm AAR or more) to which they are adapted. Within the group, however, moisture requirements vary appreciably. For example, setaria does not recover well from dry periods during crop growth and continuous moisture availability is essential for good seed yields. Under rain-grown conditions in the subtropics, the highest commercial yields have come from the highest rainfall districts used (c. 1,600-1,800 mm AAR) and supplementary irrigation is also an advantage, especially toward the lower rainfall limits.

Temperature influences the location of grass seed crops, first by the potential effects of low temperatures on the seed set of late-flowering grasses, and second through differences in general adaptation. Within group (c), for example, grasses such as para grow and seed well only in warmer tropical areas where other species best suited to cooler subtropical and tropical highland conditions (e.g., setaria, paspalum) would not succeed.

Seed Production in Marginal Environments

In some cases, it may be necessary to undertake seed production in an unsuitable climate, although this should only be considered as a last resort. For example, the range of available climates may not be sufficient in a small country where it is also not economically possible to import seed. In such circumstances, it may be possible to increase the chances of success by modifying the best available climate to some extent. In particular, careful site selection based on local experience can reduce or eliminate the risk of frost in marginal environments. With many legumes, irrigation is a satisfactory biological substitute for rainfall, though some legumes (e.g., creeping vigna - Vigna parkeri) and most grasses from higher rainfall environments (e.g., setaria) also seem to need accompanying humidity. With twining legumes (e.g. siratro), the use of trellises or even a growing upright framework such as rows of maize may improve seed production in marginally wet and marginally frosty environments: the exposure to either better light or a drier microclimate seems to stimulate flowering and reduces disease, and the greater elevation helps avoid light ground frosts.

Soils

Seed crops of both grasses and legumes can be grown on a wide range of well-drained soils. However, soil requirements for different cultivars vary and a good agricultural soil is not always the best option: it is the adaptation of the particular plant that determines the suitability of different soil types, not personal prejudices based on what is appropriate for annual field crops. For example, setaria will grow on relatively poorly drained soils that are not suitable for Inverell purple pigeon grass, a member of the same genus. In general, however, a soil with good moisture-holding capacity is an advantage with grasses in providing a buffer against vagaries in the amount and the distribution of rainfall and against inefficient irrigation. By comparison, soil fertility is usually less important provided fertilizer can be applied to correct any nutrient deficiencies.

Greater weed competition can be expected on fertile soils, especially in old cultivations. With the shorter, less competitive legumes in particular (e.g., lotononis, Bargoo jointvetch, fine-stem stylo), lower fertility soils are therefore preferred for seed production. Similarly, for seed crops in general, newly cleared land is often used to reduce competition.

ESTABLISHMENT

The same general principles apply to the establishment of pastures and the establishment of pasture seed crops. The major difference lies in the "thickening up" phase that normally follows the initial phases of seedling emergency and establishment in pastures. In contrast, the aim with seed crops is to eliminate, or at least drastically reduce, the need for any thickening up of the initial plant population (Fig. 1).

Where a pasture sward is being established specifically for seed production, it should be regarded primarily as a "crop." As such, it warrants more care and expense during establishment than pastures sown for grazing. Land preparation is generally more thorough to give a clean, firm, fine seedbed. High-quality, readily germinable seed is preferred and, as a rough rule of thumb, seeding rates should be about twice those recommended for normal pasture sowings. The temptation to reduce seeding rates when multiplying scarce or expensive seed must be resisted: it is always better to establish a smaller area properly than to risk stretching the seed too far. Inoculation of legume seed before sowing is a cheap insurance against failure, especially where legumes have not previously been sown.

Fig. 1. A dense weed-free seed crop of roundleaf cassia (Cassia rotundifolia cv. Wynn) 4 months after sowing in southern Queensland.

Because the seeds of most pasture plants are relatively small, they are generally sown on the surface or lightly incorporated to no more than about 1 cm depth. The seedbed should then be rolled to improve seed-soil contact.

In Queensland, seed is often mixed with fertilizers (usually superphosphate) to facilitate distribution and two precautions are necessary. First, legume seed should be pelleted to protect the inoculum. Second, mixtures of superphosphate and unprotected grass seeds must be sown immediately as the acid conditions can reduce germination even after storage overnight.

In theory, row planting has long been recommended for pasture seed crops to assist in the rogueing of off-types and to allow for interrow cultivation, similar to the situation with a number of annual field crops. In practice, the adoption of row planting with pasture seed crops has been limited, and the use of interrow cultivation is even less widespread despite the sometimes good intentions of growers. Row-planting is of greatest value with the tree legume leucaena (Leucaena leucocephala), with vigorous sprawling legumes (e.g., stylo), and with tussock grasses (e.g., Panicum and Setaria spp.) where the highest seed yields have been obtained from particular row spacings (Boonman 1972a; cf. Hacker and Jones 1971). With maximum productivity depends on the early formation of a closed canopy where soil moisture and nitrogen are adequate, although wider rows are advisable if either factor is likely to be in short supply (Loch 1982; Boonman 1973). Broadcast sowings may be equally useful or even preferable with other plant types, including stoloniferous plants such as Rhodes (Boonman 1972b), creeping bluegrass, lotononis, and Kenya white clover, and shorter, less-competitive legumes (e.g., fine-stem stylo, Bargoo jointvetch).

Because of its annual habit, Townsville stylo (Stylosanthes humilis) must be reestablished each year and control over plant density is necessary to maintain seed production (Shelton and Humphreys 1971). Similar considerations apply to Verano Caribbean stylo, which must be renovated annually because perennating plants lack vigour. Plant density can be controlled by the number of cultivations before reestablishment, or by thinning the seedlings with spike harrows or paraquat sprays (although the rate and the droplet size are critical).

Weed control cannot be overemphasized and should begin during establishment. The various options include pre-plant-incorporated or pre-emergence herbicides applied to the seedbed (Hawton 1976, 1980; Hawton and Johnson 1980), selection of planting time (Johnson and Hawton 1980), and hand weeding where cheap labour is available. The "stale seedbed" technique is not often used because of the time required, but it can be very effective in controlling populations of weeds that are resistant to selective herbicides; it follows normal seedbed preparation and involves the destruction of up to three successive germinations of small weed seedlings with desiccant herbicides before the crop is sown into the stale seedbed with a minimum of soil disturbance.

MANAGEMENT

Recent articles by Hopkinson and Eagles (1980) and Loch (1982) indicate the major aspects that must be considered with new seed crops. However, it is best to treat legumes and grasses separately because of differences in emphasis between the two groups.

Legumes

Effective weed control is a prerequisite to successful long-term seed production of legumes. After establishment, the first objective with the bulkier tropical species is to produce a dense closed vegetative canopy as early as possible. This helps to smother weeds and provides a framework for later crop development. Where cheap labour is available, hand weeding and hoeing are probably the best means of maintaining a clean, weed-free crop. Alternatively, post-emergence herbicides can be recommended for broadleafed weed control in several crops (Hawton and Johnson 1980), although there is less information on the "subtropical" plants that generally compete less strongly with weeds. These methods can be supplemented by rope-wick weeders that are both a cheap and an effective means of removing taller growing weeds from shorter non-twining legume crops; in particular, inexpensive hand-operated versions (called chemi-hoes) could usefully extend the range of options available with hand labour. Recent results with the new herbicide fluazifop have also been encouraging: all but a few grass weeds appear to be controlled, particularly in the seedling stage, without harming legumes.

Adequate nutrients, insect control, and disease avoidance are required for healthy, productive crops. Insects in particular must be considered. These include the various lepidopterous larvae that feed on pods and flowers, sucking bugs that also affect pods and flowers, and root-eating coleopterous larvae that are the most difficult to control.

Cutting management varies. In Queensland, axilleris crops are allowed to build up gradually throughout the growing season. However, crops of rampant short-day legumes such as stylo, may be trimmed c. 4-6 weeks before floral initiation, thereby reducing the bulk and allowing plants to recover by the start of the reproductive phase; cutting too late simply delays flowering, prolongs the reproductive phase, and reduces seed yields (Loch et al. 1976). In contrast, terminal and axillary shoots of lotononis and Kenya white clover need exposure to light for proper floral development. Swards should therefore be maintained in a short, open condition by regular cutting or close grazing until flower buds are produced.

Irrigation strategy also varies. Siratro and centro are instances where changes in soil moisture override the effects of daylength in the field. In districts with a reliable dry season, flushes of seeding can be induced by alternating periods of irrigation and moisture stress as described by Hopkinson (1977). In contrast, lotononis and Kenya white clover require adequate winter moisture to maintain a strong vegetative framework for the eventual seed crop; however, watering should cease with the onset of warmer spring weather to avoid excessive vegetative growth that encourages head rots and makes harvesting difficult.

Grasses

With grasses, the overall aim of management is to produce synchronized, high-yielding crops by promoting the uniform development of dense inflorescence populations. This depends largely on the combination of cutting management and fertilizer N to encourage the rapid early production of new tillers that form the basis of a synchronized crop.

Where possible, grasses should be grazed between cropping cycles so that a lenient cleaning cut is carried out at the start of the new crop. A severe cleaning cut can delay regrowth, prolong inflorescence emergence, and may ultimately result in fewer inflorescences (Loch 1983b).

In equatorial regions and with daylength-insensitive grasses at higher latitudes, flowering can occur throughout the year, allowing cleaning cuts to be timed according to anticipated growing conditions. Away from equatorial regions, however, the timing of cleaning cuts on short-day grasses such as Callide and Samford Rhodes, creeping blue, and gamba is related to their restricted periods of flowering (Loch 1980; Andrade et al. 1983). During autumn, these grasses do not seed earlier if a cleaning cut is carried out before the latest safe dates; rather, they simply produce taller, bulkier plants that are more difficult to harvest.

Nitrogen is regarded as the main nutritional determinant of grass seed yield. The necessary fertilizer should be applied as a single dressing as soon as possible after the cleaning cut. Established stands require more N fertilizer than 1st year crops and the optimum level also depends on species, cultivar, soil, and rainfall. In practice, the need for fertilizer N can be reduced by regular renovation through cultivation or by effectively "mining" naturally fertile soils after clearing as has been done for a number of years in arable districts of central Queensland.

The best grass crops are produced when there is no moisture stress to affect synchronization and reduce individual components of seed yield. Although satisfactory results have been obtained with many grasses under rain-grown conditions in suitable localities, supplementary irrigation improves the reliability of cropping and increases yields. It is of particular importance during the early stages of seed increase, and with moisture-sensitive species (e.g., setaria) or late-flowering cultivars (e.g., Callide and Samford Rhodes).

Weed control measures are less critical than with legumes because well-fertilized, established grass seed crops compete strongly with contaminant species. In general, insects and diseases also pose fewer problems than with legumes, although some potentially damaging diseases have so far been excluded from Queensland by quarantine measures. Plagues of rats and mice, however, occasionally wreak havoc with ripening grass seed crops in the field.

TIME OF HARVEST

Proper choice of harvest time is important, particularly where a single destructive harvest is to be taken from the standing crop. The period over which high yields of good-quality seed can be harvested varies considerably and depends both on the cultivar and on weather conditions, especially wind and rain. Peak presentation seed yields are maintained for only short periods in many crops such as stylo, desmodiums, lotononis, purple pigeon grass, and green and Gatton panics; in other cases, however, the timing of harvest is less critical because of the longer periods of peak yields (e.g., shrubby stylo, Kenya white clover, setaria).

Various indicators can be used to determine when to harvest, although all are easier to apply with a well-synchronized crop. In legumes, these include the degree of pod shattering and the proportions of mature and immature pods and flowers, as well as the quantity of ripe seeds that can be shaken from plants (e.g., stylo). With grasses, the main visual indicators are the ease of seed removal (coupled with biting or rubbing of the seed to check for the presence of caryopses), the amount of seed shed, and changes in overall field colour that reflect changes in seed pigmentation during maturation in many grasses. All of the available indicators of ripeness, however, are subjective; and for an accurate assessment of the overall stage of crop maturity, there is no substitute for experience aided by a keen sense of observation.

METHOD OF HARVEST

A variety of harvesting methods can be used. Regardless of which method is adopted, care should always be taken to ensure that the harvested sample can be cleaned to the required purity standards with minimum wastage of seed and time.

Hand Harvesting

Hand-harvesting methods are the simplest and also the most logical to use where labour is plentiful and cheap. These include hand-picking of legume pods (e.g., siratro, leucaena), which can be repeated on the same area at regular intervals over a prolonged period, and hand-sweeping from the ground during the dry season where crops (e.g., Townsville stylo, Caribbean stylo, signal grass) have been allowed to ripen and shed. Grass inflorescences may be cut above the leaf canopy with sickles (Fig. 2), taking care to remove any weeds; these are then bound and stooked to cure in the field for about 2 weeks before threshing, normally by beating the seed out with sticks on a sheet. For chaffy-seeded grasses (e.g., buffel), a hand-stripper can be easily constructed by attaching nails to a bar at appropriate intervals; when this is drawn through the

Fig. 2. Hand harvesting of Rhodes grass (Chloris gayana) seed in Ethiopia.

crop, ripe seeds are stripped into a bag trailed behind the collecting bar. A similar device with a tray rather than a bag has also been used to collect ripe seeds from fine-stem stylo.

In countries with high wage structures, there has been a trend toward mechanization. Larger areas can be harvested quickly with less labour, although yields and quality of seed tend to be lower than from hand-harvesting.

In Queensland, for example, combine harvesting with conventional self-propelled machines fitted with open fronts is now the main method of harvest for most grass and legume seeds. The standing crop is usually harvested direct, but prior windrowing is practiced with the desmodiums, some crops of glycine and lotononis, and occasional grass crops when rainfall is unlikely. Specialist seed growers tend to produce heavier seed crops and generally choose machines with relatively narrow fronts so that their threshing and cleaning capacities are not overtaxed by the amount of bulk taken in at the front.

In north Queensland, larger and more expensive machines can be justified because pasture seed crops are combined with large areas of annual field crops. The recent trend toward these has greatly improved the recovery of seed from the bulkier tropical legumes (largely through brute force) and also signal grass where substantial quantities of fallen seed are recovered from the mat of horizontal leaves by harvesting very low. In contrast, annual field cropping is more restricted in coastal southern Queensland and less power is required to handle the grasses and the less bulky subtropical legumes grown there; smaller machines (usually purchased secondhand) are therefore used because of the risks associated with pasture seed production. In the case of opportunist harvesting (e.g., in central Queensland), wider fronts can be used to increase the rate of harvest because lighter crops are produced.

The progression toward combine harvesting includes the reaper and binder that mechanizes the collection and binding of inflorescences into sheaves. Tractor-mounted mowers are still used by some north

Queensland farmers to collect guinea grass inflorescences that are "seated" in moist heaps for a few days before shaking out the detached seeds and drying them. A leucaena stripper has also been designed in central Queensland using an overhead boom arm from the three-point linkage to strip ripe pods onto a trailer/sledge drawn behind the tractor.

Over the years, a variety of special machines have been built -- often in farm workshops -- for the selective recovery of mature grass seed. They allow multiple harvests to be taken from the same crop and are of particular value with chaffy-seeded grasses (e.g., buffel, creeping blue), although Pioneer Rhodes and smooth-seeded species such as the panics have been harvested in the past. Most of these machines are comparatively inexpensive, particularly the earlier ones described by Cull (1963) and Purcell (1969). The simplest type is an open box covered with gauze at the top and the back and possibly with tensioned wires across the front; it is mounted on a vehicle and driven through the crop at c. 20-30 kilometres per hour (kph). This basic design has been improved, largely by mounting independent beaters or wire brushes in front, to give a second group of machines that operate at much safer speeds of c. 5-8 kph. More recently, modified combine harvesters and cotton pickers (typically with large beater-type fronts, high cleaning capacities, and collecting bins that can be emptied quickly) have been used in the Callide-Dawson area of central Queensland.

In the USA, difficulties with chaffy-seeded grasses (mainly *Bothriochloa* and *Dichanthium* species) have also generated special harvesting machinery, culminating in the OSU (Oklahoma State University) grass seed stripper (Whitney et al. 1979) and the Woodward flail-vac seed stripper (Beisel 1983; Dewald and Beisel 1983). In particular, the latter design represents a radical departure from beater-type machines because it is based on the use of brush rotating away from the machine and upward at the leading edge.

The recovery of fallen legume seed has been mechanized by pneumatic harvesting (commonly called suction or vacuum harvesting because of the most widely used type of machine). This was developed for subterranean clover and medic seeds in southern Australia. For efficient recovery, the soil must be hard and dry with an extremely level surface free of vegetation; preparations therefore begin at the time of sowing. On the debit side, suction harvesting is an extremely slow and dirty operation involving specialized, expensive machinery, and the removal of weed seeds and large volumes of soil during cleaning becomes progressively more difficult and expensive with smaller-seeded legumes. In practice, suction harvesting is mainly used either with light seed units where the true seed is enclosed in a pod segment (Townsville, Caribbean, shrubby, and fine-stem stylos) or with relatively large dense seeds (siratro). Other methods of harvest are preferred where a high proportion of total seed yield is carried on the standing crop at some stage.

DRYING

Seed harvested from the standing crop may be dried in shallow layers on sheets in the sun or an airy shed, or in artifical batch dryers. With moisture levels of up to 50-60% or more, drying should commence as soon as possible after harvest, at the most within a few hours, and continue without interruption until completed. The required capacity for artificial dryers depends on the maximum amounts of seed harvested per day. High levels of relative humidity (e.g., at night) need to be lowered by heating the air if drying is to continue. A maximum temperature of c. 35 °C is commonly regarded as safe. General principles of seed drying have been reviewed in a number of papers (e.g., Nellist and Hughes 1973) and the advantages of slow-drying for certain smooth-seeded grasses (Hopkinson 1976) should also be noted.

SEED PROCESSING AND PACKAGING

Seed processing aims at producing good-quality seeds that meet the recommended standards for germination, weed freedom, and seed size. Because processing is less urgent than harvesting or drying, it generally takes place sometime later and at slower daily rates. Allowance must be made for temporary storage of dried, uncleaned seed that can also be transported to more distant processing facilities if necessary.

Various authors have discussed seed processing (e.g., Vaughan et al. 1968; Linnett 1977), which is based essentially on screening and winnowing. In more traditional situations, hand methods may be supplemented very cheaply by a simply constructed winnower (Verhoeven 1964) provided a suitable fan is available (Fig. 3). In large cleaning plants, the main cleaning machine will operate faster and more efficiently with a precleaner to remove the larger trash; it may also be followed by length and gravity separators, or replaced by special machines (e.g., buffel grass cleaners) to cope with particular difficulties. It cannot be overemphasized that clean seed comes from clean fields; no amount of seed cleaning after harvest can compensate for inadequate weed control in the growing crop.

After processing, seed should be packed into new bags, either polypropylene or jute, to avoid contamination. Dry sealing of seed with thick polyethylene liners for longer-term storage can also be carried out at this stage. Bags should be packed to standard weights to facilitate subsequent handling.

SEED TESTING

Seed testing (e.g., Harty 1980) provides the basis for regulatory controls over seed quality, for price and consumer discrimination among available seed lots, and for the adjustment of sowing rates. Appropriate procedures are gradually developed for new cultivars and eventually become accepted into the rules of the International Seed Testing Association.

Separate specialized laboratories for the routine testing of pasture seeds and other seeds are generally not warranted. A mixed laboratory has advantages of spreading the workload more evenly throughout the year and of providing wider experience for testing staff.

Fig. 3. A simple, inexpensive winnower described by Verhoeven (1964).

SEED CERTIFICATION

The high level of pasture seed certification in temperate countries is not necessarily appropriate to tropical and subtropical situations at the current stage of development. Local needs and objectives need to be critically examined before certifying a new cultivar. In

Queensland, certification (usually on a pedigree basis) is offered where there is a risk that cheap seed of an inferior cultivar will contaminate, or be substituted for, expensive seed of a desirable cultivar (Loch and Friend 1980). In general, the pasture seed industries do not place high priority on varietal uniformity and stability, and are reluctant to pay the extra cost of maintaining it. To date, there has been no critical study of genetic drift in tropical or subtropical plants, and there is a suspicion in scientific circles that variability and the capacity for varietal change may be useful adaptive attributes, particularly in pioneering situations.

SEED STORAGE

Seed storage is particularly important in tropical countries where high temperatures and humidity combine to accelerate the loss of viability and are unsuited to anything other than short-term storage. Seed at 10% moisture content (MC) will store well at most ambient temperatures, but can regain moisture from the air and quickly rise to the danger level of 14% in humid weather and begin to deteriorate rapidly.

Several recent reviews of seed storage are available, (e.g., Delouche et al. 1973; Justice and Bass 1978; Arvier 1983; O'Dowd and Dobie 1983) and seem generally applicable to pasture seeds. In particular, seed longevity depends both on the state of the seed entering storage and on the conditions of storage. Facilities required depend on the anticipated quantities of seed and the expected length of storage in each case. These range from a well-ventilated rodent-proof shed without any localized "hot spots" for short-term storage (less than 1 year) to dry sealing of carryover seed at 10% MC for longer term storage.

ROLE OF RESEARCH

With any new cultivar, the greatest barrier to successful seed production is ignorance of its requirements. This is the situation with many of our new pasture plants that have only recently been plucked from relative obscurity, hence the need for research.

The specialist nature of seed production research was recognized in Queensland in 1970 with the appointment of two scientists by QDPI. This has enabled concentrated work on many aspects of seed production technology in contrast to earlier piecemeal work by part-time researchers. Emphasis has also been placed on applied research involving a research phase to generate results followed by a development phase to apply these results in larger-scale commercial practice. Research personnel should be closely involved in the development phase because it is their knowledge that is being applied; moreover, the feedback during application helps to formulate future research more realistically. At the time of release, the current state of the art should be summarized as a guide to seed producers; this recipe can then be updated progressively in the light of subsequent experience (see the example in the Appendix).

Where little is known about the seed production of a new cultivar, a two-stage approach (Loch 1982) is preferred. It initially involves making a detailed record of crop growth and development, including seed production and loss. This is done under standard management conditions at a single site in a single-treatment sequential harvesting experiment or in combination with a single management variable (e.g., N in grasses). In this way, some understanding of the new crop is gained before seeking solutions to its problems in subsequent work. Ideally, such research should start just before release to provide information for commercial growers, although in practice this is not always possible. In lieu of more complete information, experience gained during the previous multiplication of seed on experiment stations can provide a useful guide, particularly if supplemented by more detailed experience with other crops of similar morphology and flowering behaviour. For legumes, herbicide tolerances can be checked by rapid screening in the field (e.g., broadleaf cassia -- Appendix), although formal experiments are necessary before chemical registration can be sought and definite recommendations made.

ADDITIONAL SOURCES OF INFORMATION

The technology of pasture seed production is a large topic that cannot be reviewed in detail in a single short paper. Additional information on particular aspects can be obtained from a number of useful publications in addition to those references already given. The more general of these include the book by Humphreys (1979) and articles dealing with specific countries (e.g., Boonman 1979, 1980; Rayman 1979; Hare and Waranyuwat 1980) or specific crops (e.g., Hopkinson and Loch 1977; Hopkinson and English 1982; English and Hopkinson 1983). Special mention must also be made of the booklet by Harding (1980); it contains much valuable information on practical aspects of seed production in general and that of a number of little known grasses and legumes.

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APPENDIX -- CROP SUMMARY EXAMPLE

Wynn Roundleaf Cassia

Roundleaf cassia (Cassia rotundifolia) is a new legume for subtopical areas. The first cultivar, Wynn, was released in Queensland in 1983. It is perhaps best described as a self-regenerating, short-lived perennial.

Establishment

It is important to establish seed crops of Wynn only on well-drained soils. Poor drainage restricts plant growth, thereby allowing weeds to dominate the sward. Freedom from nut grass (Cyperus rotundus) is also important because this plant cannot be controlled adequately in the seedbed and competes strongly with establishing seedlings of Wynn.

Seed should be scarified mechanically to reduce hardseededness if necessary and inoculated with Group I inoculant before being broadcast at 4-5 kg/ha onto a well-prepared seedbed with pre-plant-incorporated trifluralin; very shallow incorporation of seed may give better results in the drier subtropics and tropics. The seedbed should be rolled after sowing. Rates of 250 kg molybdenum superphosphate and 100 kg muriate of potash at establishment have been suggested for infertile soils. Because machinery must subsequently be operated as close as possible to the ground to harvest the standing crop, the paddock surface should be stick-free and as even as possible.

Flowering Behaviour

Wynn appears insensitive to daylength and will flower throughout the growing season provided adequate moisture is available. Crops can be harvested when a sufficient bulk of material has accumulated and is carrying large numbers of ripe pods.

Management

Post-emergence weed control is important because Wynn can be severely retarded by weed competition. Preliminary screening of herbicides indicates that bentazone (at 3 L/ha of 48% products) and dinoseb (at 4 L/ha of 20% product) can be safely used for broad-leafed weed control. Grass weeds can be sprayed with fluazifop (at 1-2 L/ha of 21.2% product), either to kill these in the seedling stage or to set back established plants while the crop develops. Wick-wiping with concentrated glyphosate is also a useful method of weed control.

Annual maintenance dressings of up to 125 kg superphosphate and possibly 50 kg muriate of potash/ha may be warranted. Molybdenum at c. 100 g/ha should also be applied every 3 years to ensure continued productive growth.

Heavy infestations of green vegetable bug (Hezara viridula) during flowering and seeding can severely reduce the yield and the quality of seed if not controlled by spraying with a suitable insecticide (e.g., endosulfan at 2.1 L/ha of 35% product, methomyl at 1.5 L/ha of 22.5% product). These sucking insects feed on the developing pods, resulting in a high proportion of shrivelled seeds even though the pods externally appear normal (i.e., not misshapen or twisted).

Harvesting

Unless flowering ceases due to moisture stress, the timing of harvest does not seem critical. Where crops are flowering continuously, standing seed yields apparently remain near the peak for prolonged periods because the loss of seed from the shattering of ripe pods is offset by new pods entering the system.

High yields of more than 200 kg cleaned seed/ha/crop can be produced by direct-heading with a conventional combine harvester. A drum speed of c. 1,000 rpm with the concave nearly closed and a light flow of air over adjustable sieves has given satisfactory results. Because of the continuous flowering nature of Wynn, more than one seed crop may be harvested during the growing season from the same area, particularly under irrigation.

Large quantities of seed accumulate on the ground as a result of continuous flowering coupled with the ready shattering of ripe pods. This also provides scope for suction-harvesting and hand sweeping.

EVALUATION OF THE NUTRITIVE VALUE OF FORAGES

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Abstract *Basic biological principles and techniques adopted in the evaluation of the nutritive value of forages are reviewed in two sections. The first presents a discussion on the current concepts of the energy and protein value of forages and examines some of the factors influencing the digestion and metabolism of carbohydrate and nitrogenous components. Attention is drawn to the importance of determining the chemical entities and degradation of OM and N in the rumen. The ME and new protein feeding systems have been noted as they affect new concepts in evaluation systems.*

In the second section, a discussion is presented on some techniques for the evaluation of the energy and protein value of forages. This includes in vivo and in vitro apparent digestibility, in sacco rate of degradation of carbohydrates and protein, in vitro degradation of protein by rumen microbes, and protein solubility and N balance.

As knowledge increased on the understanding of the biological activities operating in the utilization of ingested nutrients by the ruminant animal, the techniques of evaluating the nutritive value of feedstuffs also were modified and refined. Efforts in developing a system of evaluating the nutritive quality of feeds should help predict: (a) the voluntary intake by the animal, (b) the possible end-products of digestion in the rumen and postrumen, and (c) the eventual utilization of the end-products of digestion at the tissue level.

The current state of knowledge recognizes the dynamic interrelationships existing between the chemical nature of the diet, rumen metabolic functions, and tissue metabolism. Various researchers have attempted to develop dynamic simulation models of ruminant digestion (Baldwin et al. 1977; Beever et al. 1980-81) and nutrient utilization (Graham et al. 1976) to help identify the factors influencing the nutritive value of feedstuffs.

In the model by Baldwin et al. (1977) and Black et al. (1980-81), the composition of dietary inputs was described in terms of chemical entities rather than proximate values. Considering the limitations of the proximate system (Van Soest and Robertson 1980; Van Soest 1982) the use of chemical entities in the models is a step forward. The microbes in the host animal do not metabolize proximate or other empirically defined entities as specific dietary components (Baldwin et al. 1977), whereas, compounds such as sugars, starch, pectin, cellulose, etc., can be selectively metabolized and serve as sources of energy, and protein, free amino acids, and nucleic acids, etc. as sources of nitrogen. Plant tissues contain these material entities (Van Soest 1982).

More relevant chemical methods, therefore, to evaluate feedstuffs, which reflect the actual composition, are required to make a relatively accurate prediction of the nutritive value to the animal. Values of chemical analyses need to be combined with biological evaluation comprising voluntary intake, ruminal digestion, and host-animal response.

In this review some aspects of digestion and metabolism of carbohydrate and nitrogenous components will be discussed, together with techniques used to measure degradation of these components in the rumen. Comments are also made on the conventional digestibility and nitrogen balance studies in relation to forages.

RELATION OF CARBOHYDRATE AND PROTEIN DIGESTION AND METABOLISM TO FORAGE EVALUATION

Carbohydrate Components

Various carbohydrate components serve as the major source of energy to the microbes in the rumen.

volatile fatty acids (VFAs), the end-products of fermentation of carbohydrate components, are the main source of metalizable energy (ME) to the host animal. Forage carbohydrates comprise sugars (glucose, sucrose, and fructose), starch, pectin, cellulose, and hemicellulose (Van Soest 1982). The structural carbohydrates, such as cellulose and hemicellulose, ferment slower than starch and soluble carbohydrates like sugars ferment rapidly (Van Soest 1982). The potential extent of digestion of the components could be affected by the content of lignin (Van Soest 1982).

Despite similarities in the overall digestibility of organic matter (OM), differences in gross efficiency of utilization between forages could arise due to differences in sites of digestion of carbohydrates and nitrogen (Ulyatt and MacRae 1974). As shown in Table 1, the differences between Lolium perenne, L. perenne x Lolium multiflorum and Trifolium repens in the apparent digestibility of OM are slight, but the digestibility of OM at different stages in the digestion process is considerably large (Ulyatt and MacRae 1974). These differences have important implications on the utilization of N, and, therefore, on the nutritive value of the species.

From various studies (Beever et al. 1978; Hogan and Weston 1969; Ulyatt and MacRae 1974; Ulyatt and Egan 1979) it has been determined that more than 94% of readily fermentable carbohydrates, about 91% of digestible cellulose, and 85% of digestible hemicellulose (in fresh herbages) appear to be digested before entering the small intestine. Based on this information, and from the data collected on the chemical entities of OM and their apparent digestibilities, it might be possible to estimate the extent of their digestion in various sites and their contribution in energy to microbial synthesis and host animal (Egan 1975). However, the rate and extent of digestion of various carbohydrate components in the rumen can be measured using the synthetic fibre bag technique. This technique is simple, less costly, and provides a rapid and relatively accurate method of measuring the rate and extent of dry matter (DM) degradation (Ørskov et al.1980).

A higher content of soluble carbohydrate is known to result in a more efficient fermentation in the rumen

Table 1. Carbohydrate contents of fresh forages and their digestion when fed to sheep.

Forage	Chemical composition (% DM)[a]					Apparent digestibility (%)					
	Readily fermentable carbohydrate		Structural carbohydrate		OM[c]	% In stomach (% digestible)				In small intestine	
	WSC[b]	Pectin	Cellulose	Hemicellulose	(Overall)	WSC	Pectin	Cellulose	Hemicellulose	(% digest.)	Reference
<u>L. perenne</u>	8.8	1.4	18.2	11.8	80	- 94 -		90	92	18	Ulyatt and MacRae (1974)
<u>L. perenne</u> x <u>L. multiflorum</u>	11.1	1.4	16.9	10.7	81	- 93 -		90	88	30	"
<u>T. repens</u>	9.7	10.3	12.1	3.8	82	- 94 -		91	81	23	"
<u>L. perenne</u>	12.5	1.7	19.0	12.0	84	93	100	92	88	--	Ulyatt and Egan (1979)
<u>L. multiflorum</u>	12.8	1.3	16.6	9.6	87	91	100	88	80	--	"
<u>T. repens</u>	11.6	10.1	13.9	3.9	84	89	96	92	78	--	"
<u>O. viciifolia</u>	9.8	9.8	15.5	5.0	74	90	95	96	91	--	"
<u>L. perenne</u> (spring cut)	19.3	nd[d]	29.4	19.9	74	93	nd	89	87	25	Beever et al. (1978)
<u>L. perenne</u> (autumn cut)	12.4	nd	25.5	19.2	70	92	nd	92	87	35	"

[a] DM = dry matter.
[b] WSC = water soluble carbohydrate.
[c] OM = organic matter.
[d] nd = not determined.

(Beever et al. 1978). With readily fermentable carbohydrates almost completely fermented in the rumen no, or very little, glucose from forages enters or is absorbed from the small intestine (Ulyatt and MacRae 1974). High concentration of readily fermentable carbohydrates (Table 2) in the herbage could result in an increased supply of propionic acid (Tilley et al. 1960, Hogan and Weston 1969; Beever et al. 1978). Propionic acid serves as a precursor for glucose synthesis (Beever et al. 1978).

It has been noted earlier that the major sources of ME to the host animal are the VFAs absorbed from the rumen. The measurement of ruminal VFA production, with detailed chemical analysis of the forage carbohydrate components, might aid in the assessment of the possible contribution of ME to the host animal (Table 2).

The effects of N fertilization (Hogan and Weston 1969) and maturity of forage (Hogan and Weston 1969; Hogan et al 1969) in lowering the soluble carbohydrate content and reduced ME contribution are shown in Table 2. Low water-soluble carbohydrates result in higher proportions of acetic acid and lower proporations of propionic acid. The efficiency of utilization of acetic acid by the host animal is low, and is dependent on the availability of glucose or glucose precursors (Hovel and Greenhalgh 1978). The effects of molar proportions of propionic acid from various forages on the efficiency of energy utiization is illustrated in Fig. 1.

Based on the points mentioned earlier it is desirable to examine the chemical composition of forages in terms of the carbohydrate entities rather than the proximate crude fibre (CF) and nitrogen free extractives (NFE). The combination of these with data made available on the rate and extent of digestion of the entities in the rumen could assist in the identification of the possible reasons for the differences between species in nutritive value. Coefficients of overall apparent digestibility could be misleading as measures of nutritive value (Ulyatt and MacRae 1974; Beever et al. 1978) under certain conditions.

Table 2. Concentration of water soluble carbohydrate (WSC) in fresh forages fed to sheep, proportion of volatile fatty acids (VFAs) in the rumen, and estimated quantities of metabolizable energy (ME) (Kcal) available from the VFAs.

		Molar % of total VFA			ME contribution (Kcal)/100 g OM intake				
Forage	WSC	Acetic	Propionic	Butyric	Acetic	Propionic	Butyric	Total	Reference
	(% DM)								
White clover	6.0	65	21	14	-	-	-		Tilley et al. (1960)
Perennial rye grass	7.9	63	22	15	-	-	-		
Cocksfoot	10.2	61	25	14	-	-	-		
Timothy/meadow fescue	12.9	58	26	16	-	-	-		
Lucerne	7.8	58	26	16	-	-	-		
	(% OM)								
P. tuberosa									
Early forage	20.9	66	20	11	89	58	40	187	Hogan et al. (1969)
Mid season	15.1	68	20	10	58	38	35	131	
Late forage	11.3	71	18	10	79	46	30	155	
Oats									
Maturity I									
Unfertilized	16.0	59	26	16	87	55	42	184	Mogan and Weston (1969)
Fertilized	5.0	67	21	12	99	46	32	177	
Maturity II									
Unfertilized	18.0	61	21	18	82	41	32	155	Mogan and Weston (1969)
Fertilized	8.4	64	23	13	86	45	42	173	
Maturity III									
Fertilized	5.8	67	19	14	79	33	28	140	

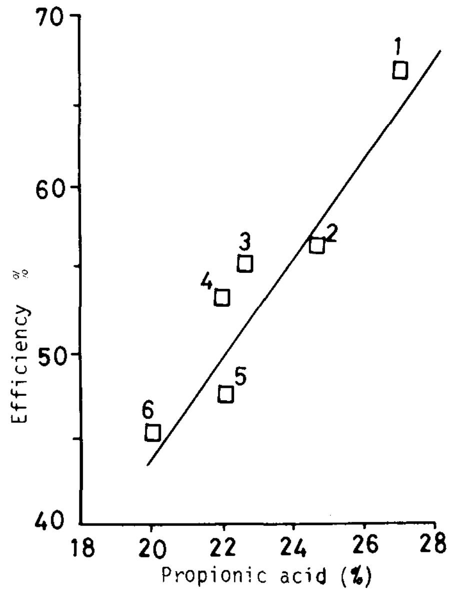

Fig. 1. The relationship between efficiency of energy utilization for growth and molar proportion of propionic acid on six pastures: 1 = ryegrass + clover, 2 = tall fescue + clover, 3 = ryegrass, 4 = tall fescue, 5 = cocksfoot + clover, 6 = cocksfoot (Grimes et al. 1968)

Relation of Nitrogenous Components of Forages to Evaluation Studies

The evaluation of the protein value of tropical grasses and legumes has to follow the current understanding of the process of N digestion in the rumen, because such processes have a considerable influence on the fate of dietary proteins. Despite the adequate amount of N, the productivity of animals from tropical grasses was found to be low, and this was believed to be due to the limitations in the contents of digestible energy (DE) (Royal and Jeffrey 1972). However, the results of Stobbs et al. (1977) showed that cows fed Chloris gayana containing 20% CP with a solubility of 40% and supplemented with formaldehyde-treated casein produced 20% more milk than from the unsupplemented diet (Table 3). Flores et al. (1979) also demonstrated that cows grazing young fertilized C. gayana increased their milk production when supplemented with 2 kg/day of fresh Leucaena leucocephala, the protein of which was less soluble than that of C. gayana. Based on the concentration of NH_3-N in the rumen, Stobbs et al

Table 3. Mean yield and composition of milk of cows fed on *C. gayana* supplemented with untreated or formaldehyde (HCHO) treated casein or *L. leucocephala*.

Diet	Milk yield (kg/cow/day)	Butter fat yield (g/day)	Protein yield (g/day)	Reference
C. gayana[a]	12.3	630	410	Stobbs et al. 1977
C. gayana + casein	12.7	660	420	
C. gayana + HCHO-casein	14.7	710	520	
% response to:				
Casein	3.3	4.8	2.4	
HCHO-casein	19.5	12.7	26.8	
C. gayana[b]	9.6	470	356	Flores et al. (1979)
C. gayana + HCHO-casein	10.1	504	385	
C. gayana + Leucaena[c] (2 kg)	10.3	502	374	
C. gayana + Leucaena (4 kg)	10.3	503	374	

[a] Composition: TN (% DM) = 3.1, Protein solubility = 40, OM digestibility = 68
[b] Composition: TN (% DM) = 2.4, N solubility = 32, D value = 62, Soluble CHO = 5.3
[c] Composition: TN (% DM) = 3.7, N solubility = 21, D value = 63, Soluble CHO = 11.9

(1977) estimated the effective protein content of C. gayana diet to be about 13% rather than the chemically determined 20%.

The incubation of Panicum maximum, L. leucocephala, and Desmodium intortum (Aii and Stobbs 1980), and Stylosanthes humilis (Playne et al. 1972) in synthetic fibre bags suspended in the rumen showed considerable differences in the disappearance of N (Fig. 2). Miller (1980) reported the disappearance of N from field beans (Vicia faba) to be lower than that of lucerne when incubated in the rumen. From this he concluded that the protein value of field bean, despite its contents of amino acids, was only comparable to urea.

Dietary N concentrations are the most widely used terms in describing the protein value of forages. Considering the differing solubility and degradation rates of N in the rumen of different plant proteins it could be misleading to use total N concentration as a measure of the protein value of forages. Solubility and degradability of protein could be used as the basis of classifying forage proteins (Hennessy 1980). The results of Aii and Stobbs (1980) demonstrated the

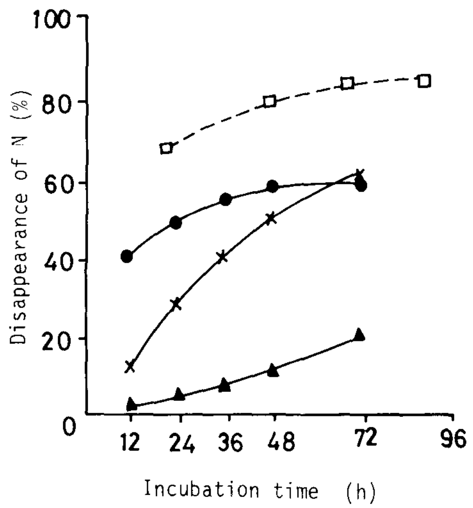

Fig. 2. Disappearance of N from synthetic fibre bags suspended in the rumen. ● = P. maximum, x = L. leucocephala, ▲ = D. intortum (Aii and Stobbs 1980); and □ = S. humilis (Playne et al. 1972)

existence of a wide variation in protein solubility between species and between different parts of the plant (Table 4).

In fresh young herbage, the DM fraction is high in N content, which is mainly in a soluble form and, therefore, is rapidly available to the rumen fermentation (Ulyatt and MacRae 1974). The degradation of high N diets could result in the production of excess NH_3, with the large proportion of it being absorbed through the rumen wall, converted to urea in the liver, and lost in the urine (Ulyatt and MacRae 1974; Klooster et al. 1977; Miller 1980). The graphs in Fig. 3 and values in Table 5 (Catton et al. 1982) illustrate the mismatching of OM supply and requirement for the efficient capture of degraded N by rumen microbes. Although the discrepancy between the requirement and the OM supplied is considerably larger for the "badly" fermented, the utilization of degraded N could be inefficient in both

Table 4. Protein solubility (%) of various plant parts in herbages (Aii and Stobbs 1980).

Forage	Cutting stage	Leaf	Stem
Grasses:			
C. gayana	Bloom	29.7	48.2
P. clandestinum	Prebloom	24.0	66.4
S. anceps	Prebloom	20.0	29.0
D. decumbens	Bloom	24.4	22.7
P. coloratum	Bloom	33.4	39.3
P. maximum	Prebloom	25.7	33.5
B. mutica	Bloom	33.5	53.0
Legumes:			
M. atropurpureum	Immature	40.8	52.9
D. intortum	Immature	7.6	15.9
D. uncinatum	Immature	5.3	36.3
A. indica	Immature	21.0	48.5
M. uniflorum	Immature	44.7	54.5

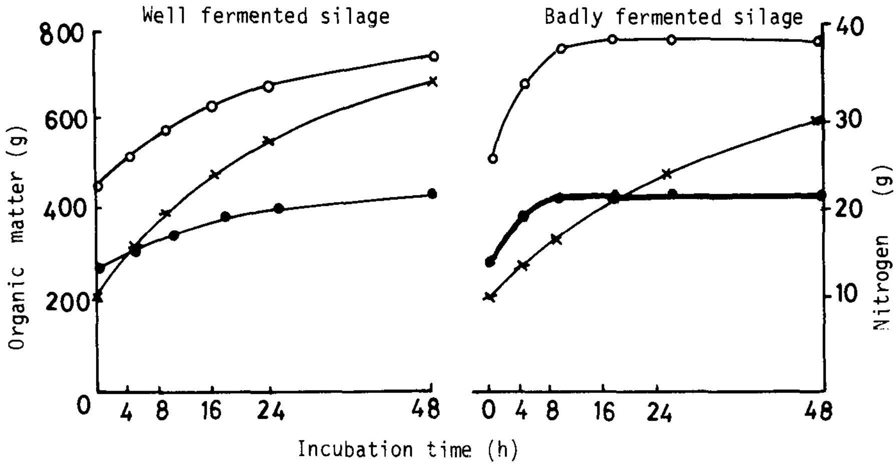

Fig. 3. Losses of nitrogen (N) and organic matter (OM) from bags over 48 hours and calculated OM requirement for each kilogram of silage DM, o = N loss, x = OM loss ● = OM requirement (Catton et al. 1982).

Table 5. Losses of nitrogen (N) and organic matter (OM) from bags and calculated carbohydrate requirement to match OM and N losses in early stages of degradation (up to 4 hours) (Catton et al. 1982).

	Type of silage	
	"Well" fermented	"Badly" fermented
Potential degradability (%)		
N	86	88
OM	76	67
Pattern of release within the first 4 hours of incubation		
N (%)	67	90
N (g/kg silage dry matter (DM)	15	20
Calculated CHO requirement to match OM and N losses during the first 4 hours of incubation (g)	239	394

silages. The synchronization of N degradation and OM release in the rumen is of paramount importance for the efficient capture of NH_3 by the microbes (Meggison et al. 1979). Illustration of the theoretical scheme of the required energy and N synchronization in the rumen is presented in Fig. 4. The effects of availability of readily fermentable carbohydrate on N utilization is shown in Table 6.

The points mentioned so far, therefore, suggest that degradability of protein in the rumen should be considered for the evaluation of the protein value of forages. To determine the degradability of forage proteins in the rumen, the dual requirements of the animal must be recognized for rumen degradable nitrogen (RDN) for microbial cell growth and the dietary N reaching the small intestine to meet tissue needs (ARC 1980; Miller 1980). Furthermore, it allows the manipulation of protein supply and minimizes the losses that could occur as a result of excessive supply of N (Fig. 5).

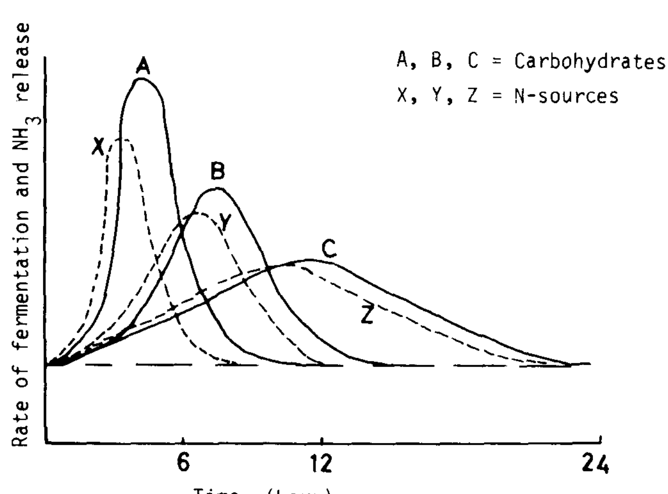

Fig. 4. Illustration of the theoretical rumen fermentation rates over time after ingestion of three forms of feed carbohydrates. (A = soluble sugars, B = starch, and C = cell wall components, and rumen NH_3 curves (-----) required to support protein synthesis from fermentation of these carbohydrates (Johnson 1976).

Table 6. Chemical composition of fresh forages fed to sheep and N intake, digestion, and utilization.[a]

Forage	Chemical composition: Readily fermentable carbohydrate: WSC (% DM)	Chemical composition: Readily fermentable carbohydrate: Pectin (% DM)	Chemical composition: TN (% DM)	Chemical composition: Soluble-N (% TN)	N intake (g/day)	App. digestibility of N (%)	NH_3 in rumen mg N/100 mL	N in urine (g/day)	N retained (g/day)	Reference
L. perenne	8.8	1.4	4.2	37	38	85	-	27.2	4.8	Ulyatt and MacRae 1974
L. perenne x *L. multiflorum*	11.0	1.4	3.8	38	35	81	-	20.6	7.6	
T. repens	9.7	10.3	3.9	50	35	82	-	24.8	3.9	
L. perenne	12.5	1.7	3.8	-	31	84	-	24.3	2.0	Egan and Ulyatt 1980
L. multiflorum	12.8	1.3	3.9	-	35	86	-	27.9	1.8	
T. repens	11.6	10.1	4.0	-	34	84	-	26.0	2.1	
O. viciifolia	9.6	9.8	3.4	-	34	74	-	20.8	4.7	
Oats:										
Maturity I										
Unfertilized	17.0	-	3.6	12.7	31	77	16	19.2	5.7	Hogan and Weston 1969
Fertilized	5.0	-	5.0	22.3	40	78	33	28.8	1.9	
Maturity II										
Unfertilized	18.0	-	1.9	12.1	14	66	11	6.6	3.2	
Fertilized	8.4	-	3.5	21.0	28	78	20	13.0	3.9	
Maturity III										
Fertilized	4.8	-	1.3	18.4	6.0	55	5	3.1	0.3	

[a]N = nitrogen, WSC = water soluble carbohydrate, DM = dry matter, TN = total N.

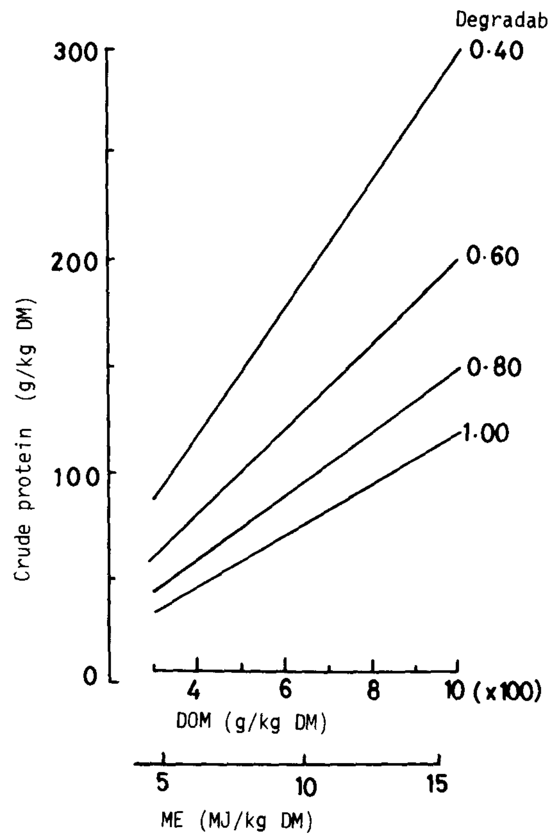

Fig. 5. Crude protein required for rumen microbes with diets differing in digestibility and protein degradability (ARC 1980).

In general, the division of N inputs into RDN and UDN (undergraded dietary nitrogen) is a simple, logical, and useful approach to supply N to the ruminant animal. Therefore, assessing the protein value of forages in terms of their degradability in the rumen instead of the traditional digestible crude protein (DCP) appears to be necessary. DCP indicates the overall disappearance of N between feed and faeces only (Klooster al al. 1977; Miller 1980). It does not indicate that dietary proteins are largely degraded in the rumen and that microbial production is related to the amount of carbohydrate fermented in the rumen (Klooster et al. 1977). In the DCP system, the excess NH_3 absorbed from the rumen is regarded as apparently digested N, and, yet, has no value to the tissue needs of the host animal (Klooster et al. 1977). Also, with DCP, it is not possible to relate the N requirements of the animal to the energy intake and concentration of energy in the feedstuffs to formulate diets (ARC 1980).

With the new protein system, however, (e.g., ARC 1980) the use of RDN and UDN estimated at a given energy input and concentration of energy in the feedstuffs is used to formulate diets (Fig. 5), i.e., once the ME requirement for maintenance and production is known then it is possible to estimate the amount of N needed for microbial synthesis (RDN) and tissue needs (microbial protein + UDN) using the following equations (see ARC 1980): (1) RDN = 1.25 ME; (2) TMN = 0.53 ME, where TMN is the tissue N supplied by microbial N; and (3) UDN = 1.91 TN - 1.00 ME, where TN is total tissue N required.

The energy value of forages could be expressed in terms of ME from digestibility data (see the section on "Apparent Digestiblity"). The use of the ME system could be a suitable basis for feed evaluation in the tropics (Van Es 1980).

Because the requirements of N and sulphur (S) to the microbes are interdependent, the estimated RDN requirement can be used to calculate for S requirements (ARC 1980): (4) S = 0.07 RDN. It is well established that S is essential for microbial synthesis and its deficiency could result in a depressed rate of digestion in the rumen (ARC 1980).

PROCEDURES FOR EVALUATING FORAGES

The preceding sections bring out the importance of a more elaborative and schematic approach in the evaluation techniques for pastures beyond the conventional systems. In this section the following schemes of pasture evaluation will be considered: chemical analyses, apparent digestibility (in vivo and in vitro), rate and extent of degradation of carbohydrates and N in the rumen (in sacco), in vitro degradation of protein, solubility of protein, and N balance.

The advantages and weaknesses of most of these techniques have been discussed by Pidgen et al. (1980) and will not be repeated here.

Chemical Analyses

Most of the data available on the chemical composition of tropical forages are of a proximate system. Based on the discussions in the previous sections, the following chemical entities should be determined: water soluble carbohydrates, starch (Smith et al. 1964), cellulose, hemicellulose, acid detergent fibre (ADF), neutral detergent fibre (NDF), lignin, lipids, ash, total N (AOAC 1975), residual-N (Batty 1972), and sulphur (Wimberley 1968).

Apparent Digestibility

The evaluation of the energy value of feedstuffs is based on the measurements of digestibility either in vivo or in vitro.

In Vivo Digestibility

Despite the amount of physical work involved and the amount of time and money required, this technique is widely used. The estimation of energy from in vivo digestibility is more reliable than it is from any other laboratory estimates (Heaney 1980).

Organic matter (OM) digestibility can be expressed as digestible energy (DE) or digestible organic matter in the dry matter (DOMD or D). The mean energy value of the digestible organic matter (DOM) in tropical forages is similar to that found in temperate forages and the following equation can be used to calculate ME (Minson 1980): (5) ME = 0.81 DE.

The expression of the energy value of tropical forages in terms of ME will allow the adoption of the new energy and protein feeding systems in the tropics. This will demand the availability of in vivo-measured ME values of forages that could serve as standards (Minson 1980).

In Vitro Digestibility

For tropical pasture species the most accurate laboratory technique to predict in vivo digestibility is the in vitro method (Minson et al. 1976). Chemical methods such as ADF and lignin predict digestibility with higher errors (Minson et al. 1976) because of the variation in the proportion of the apparent DOM arising from cell walls (Osbourn and Terry 1977).

The D-value determined from this approach can be used to estimate ME as in Equation 6 (MAFF 1975), provided the technique has been calibrated against estimates of digestibility in vivo (Moe 1980): (6) ME = 0.15 DOMD.

In Sacco Degradability in the Rumen

The synthetic fibre bags can be used in measuring the in vivo rate and extent of degradability of forage dry matter components in the rumen. In this technique (Ørskov et al. 1980), the test feed is placed in synthetic fibre bags and suspended in the rumen. The pores of the bag chosen (36 μm) are meant to allow the easy passage of rumen fluid and bacteria while retaining the insoluble dietary fraction. After incubating for a given length of time the bags are removed, washed, dried, and the residue chemically analyzed for the components, such as DM, N (Ørskov et al. 1980), and carbohydrate fractions (Catton et al. 1982). The technique gives characteristic disappearance curves from which the rate and extent of disappearance of the components can be calculated using the equation (Ørskov et al. 1980): (7) $P = a + b\ (1 - C^{-ct})$ where P = the amount degraded at time (t); a = the rapidly soluble fraction, i.e., intercept; b = the amount that will degrade in time; and c = the fractorial rate constant at which the fraction described by b will be degraded per hour.

The way in which the forages are prepared for the test may need to reflect the material that is fed, because certain treatments like drying could influence the degradability of protein (Ørksov 1982). Dry forages could be ground through a 2.5 mm screen, whereas fresh forage samples need to be minced through a 5.5 mm screen (Ørskov and Mehrez 1977) or cut to a size that will allow an adequate amount of homogenous sample (Filmer 1982). Care must be taken not to lose the juice while cutting or mincing. Because of the high moisture content of fresh forages the amount of sample in the bag should be at least 12 g, and dry forages should be 5 g (Filmer 1982).

Although the accuracy of the technique is influenced by certain factors, its simplicity and low cost (once the animal has been acquired and fistulated) and the information it provides on the degradability of the materials in the rumen will improve the evaluation of the nutritive value of forages (Ørskov et al. 1980). The usefullness of the technique for the evaluation of forages can be seen from the illustrations in Figs. 2 and 3. The rate measurements will allow the assessment of the synchronization of energy release and N degradation in the rumen.

Ayres et al. (1976) ran ruminal digestion with synthetic fibre bags concurrently with conventional in vivo digestion and found a close association between the two. The synthetic fibre-bag technique offers potential for the evaluation of forages under field conditions (Ayres et al. 1976). There is, however, an urgent need to standardize the technique, particularly the size and porosity of bags, number of bags in the rumen, form of the test material, level and type of basal diet fed to the animal, incubation time, and animal replications (Said et al. 1984).

Solubility of Protein

Although solubility is not synonymous with degradation of protein (Miller 1982), the method is an improvement in predicting the protein value of forages (Aii and Stobbs 1980).

The technique involves (Crooker et al. 1978) the mixing of ground (1 mm screen) test material containing 50 mg N and 200 mL of solvent, preheating to 40 °C with the pH adjusted to 6.5 using orthophosphoric acid (85%) in an extraction flask. After incubating for 1 hour at 40 °C with constant stirring the feed-solvent suspension is filtered. The amount of extracted N in a 50 mL aliquot of the filtrate is determined and the soluble N expressed as a proportion of total N in the feedstuff.

Sodium chloride or autoclaved rumen fluid could serve as solvents to the test (Crooker et al. 1978). Furthermore, a specific mineral mixture was used by Aii and Stobbs (1980). However, considering the shelf life and similarity of results between the various solvents (Crooker et al. 1978), sodium chloride could be preferred. For further comments on the technique refer to Verite (1980).

In Vitro Degradation of Protein by Rumen Microbes

The in vitro techniques used to estimate the degradation of protein in the rumen have generally been based on the accumulation of NH_3 released from the protein when incubated in rumen liquor (Broderick 1978; Spears et al. 1980). The technique (Spears et al. 1980) of measuring the in vitro NH_3-N accumulation involves the incubation of the feed sample in 250 mL Erlenmeyer flasks fitted with bunsen valves at 39 °C. Each flask contains 1 g of substrate and 100 mL of a 1:1 mixture of rumen fluid and synthetic rumen saliva. The quantity of NH_3-N in each flask is measured at various stages of incubation. The flasks are flushed with CO_2 initially and at each time of sampling to maintain anaerobic conditions.

The technique is not without limitations (Broderick 1978): (a) the uptake of NH_3 for microbial growth can reduce estimates of degradation particularly with feeds high in readily fermentable carbohydrates unless an inhibitor of end-product metabolism (e.g., hydrazine sulphate) is used, and (b) simple accumulation of NH_3 does not take into account the rate of ruminal passage of the protein, which has a considerable influence on the escape of protein from the rumen. The technique, however, is simple and its perfection might satisfy the need for laboratory batch tests to evaluate the degradability of proteins by microbes in the rumen.

Nitrogen Balance

Nitrogen balance studies, based on faeces and urine collection in metabolism cages, have been used widely to evaluate the protein value of feedstuffs. Because of the discrepancies in the techniques the data are used only as relative comparisons rather than absolute values (Asplund 1979). However, the measurement of retained N by the host animal supported with measurements of rates of disappearance of N and OM, concentration of NH_3 and proportions of VFAs in the rumen could enable a better interpretation of the results and, therefore, provide and improvement in the evaluation of the protein value of forages under a given condition.

Variation in N balance may be associated with voluntary intake if the animals are fed ad libitum (Asplund 1979), the balance data will reflect the state of the animal rather than the characteristics of the feed. Therefore, feeding at less than the required level is recommended to evaluate the availability of N for retention (Asplund 1979). Previous nutrition has a profound influence on the magnitude of N retention (Asplund 1979; Hovel et al. 1983; Yilala and Bryant 1984) during the test period. The adaptation diet should, therefore, be at the maintenance level (Asplund 1979).

CONCLUSION

Protein nutrition is the major limiting factor to utilize the abundant forage structural carbohydrates energy by ruminant animals in the tropics. Both the quantities and quality of N are important. Some of the findings on N availability to rumen microbes do indicate that a number of tropical forages, particularly legumes, have their proteins in protected form. The efficient use of such legumes as supplements to low-protein basal diets demands the knowledge of their chemical entities and biodegradability in the rumen. The metabolism of protein is not independent of energy metabolism. The efficient utilization of high N tropical grasses, at early stages of growth, does require the availability and release of energy at the rate that will match the rate of N degradation in the rumen. Also, in the tissues, protein synthesis is dependent on the availability of energy from high-energy phosphate molecules.

The values currently recommended to "satisfy" the nutrient needs of ruminants reflect a better understanding of the digestive and metabolic processes in the rumen and at tissue level than it was in the past. This refinement in the knowledge of the biological processes cannot be seen in isolation from the development in the techniques of measurements. In the review, attempts have been made to demonstrate the need to describe the nutritive value of tropical forages in accordance with some aspects of the current state of knowledge in ruminant nutrition, i.e., the adoption of new techniques and modifications of the conventional approaches, depending on the objective conditions, are necessary to fit into the new feeding system.

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RANGE MONITORING METHODOLOGIES

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Abstract *There are various methods used in vegetation mapping, surveying, and monitoring. The methods include aerial photography, satellite imagery interpretation, area frame sampling, step point, and the fixed transect method. Vegetation mapping and monitoring with the aid of aerial photographs is very expensive and slow. But the use of landsat imagery in vegetation mapping is fast and relatively cheap.*

Factors that determine the method to be used include time, money, and the proposed end use for the information. In Kenya, the area sampling frame method has been modified to suit our needs. Ocular reconnaissance and step point methods are fast in obtaining information on range condition, while permanently fixed line transects are used in detecting changes in plant composition, vigour, cover, and production by species.

Range management as a land-use practice began in America in areas where land cultivation was not possible. Most rangelands in Africa are used for livestock production and where part of the range is set aside for wildlife, the local people have always complained that they are being denied the use of their land. The traditional livestock production geared to the provision of food, dowry, social status, and income has resulted in increased numbers of livestock being kept on relatively small areas of land whose sizes are either constant or are being reduced.

This change is because of increased areas of land being devoted to arable cropping and that some of the land previously used by pastoralists is now being cultivated.

Rangelands are being impoverished by the impact of human activities. It is the process of change in these ecosystems that leads to reduced productivity of desirable plants and alterations in the biomass and the diversity of life forms (UNEP 1978). Plants are the most important range resource because they stabilize the soil and provide forage for livestock and wild animals and are a major source of woodfuel. According to Herlocker (1979), productivity of most of the rangeland has been reduced by human and livestock pressure and reinforced by natural hazards. Effective range management necessitates a good understanding of the relationship between the present land productivity and its long-term potential under proper management. Because vegetation integrates all environmental factors acting on a site, knowledge on its type may be used to make inferences about prevailing environmental patterns (Herlocker 1979).

Range inventories provide data for planning and executing any management proposal. There are a number of methods that have been developed in Europe and America for monitoring and preparing inventories of range resources. Some methods are fast but suffer from bias and are influenced by the person using them.

METHODS

Point Method

The point method was the logical outcome of thinking of a quadrat that became smaller and smaller until it was a point; hence, the term "point quadrat" (NRC 1962) that Mueller-Dombois and Ellenburg (1974) called the "point frequency frame method."

In the point frequency frame method, pins are lowered through holes in a box frame and all hits on the vegetation are recorded. The main advantage with this method is its accuracy. The method is recommended for studying reseeding projects or monitoring invading plants in a lawn's pitch. Arpy and Schmid and also Levy and Madden pioneered in the use of this method.

The method is, however, not advisable for sparse desert vegetation by the National Research Council (NRC 1962).

List Quadrat

When species in a quadrat are listed, the method used is called simply the "list quadrat" method. The National Research Council (NRC 1962) calls it "quadrat" only. A quadrat is a square of any selected size used in the detailed study of vegetation. The method is advisable where plants develop as individuals as in a reseeded area. The number recorded can be used as an index to any change in plant abundance (NRC 1962; Stodart and Smith 1975).

Loop Method

In the loop method, a transect line is first established, along it a 3/4 inch diameter loop or ring is dropped. All plants that appear or whose parts appear in the loop are recorded. The loop is lowered until it reaches the ground. If the crown canopy of a shrub is within the loop, a hit is recorded. This is a quick and accurate method of measuring plant composition (NRC 1962).

Capacitance Meter

Fletcher and Robinson developed the capacitance meter method for estimating herbage production (NRC 1962). The method is based on the fact that herbage has a high dialectric constant, whereas air has a low dialectric constant. By determining the dialectric constant of a plot the amount of herbage can easily be determined. The method is quick and vegetation is not disturbed.

Reconnaissance

It was reported by the NRC (1962) that the reconnaissance method was used in 1940 to estimate plant density and composition. Vegetation cover is estimated to the nearest 5 or 10%, however, the method is subject to considerable personal bias.

The worker looks over an area perpendicularly, and then estimates the amount of the area that is bare, covered by herbs, or covered by woody plants. The area being examined should be representative. This method is also simple and is recommended to ranch managers who move animals from one pasture to the next.

Step Point

In the step point method, the examiner paces through the vegetation and after every predetermined number of paces records the plant species touching the point already made on the top of the shoes. The examiner should follow a certain direction and pacing should be equal so that no bias is introduced. The method gives vegetation composition.

Line Intercept

Line intercept was described in 1941 and is based on the principle of reducing belt transect to a line with no width (NRC 1962). Canfield used a 3-m rod to get the projection of the crown spread to the tape on the ground. It gives crown cover of plants by species. The method is accurage but time consuming and can be unreliable in areas with very tall trees.

Ocular Estimate by Plot

The ocular estimate by plot method estimates herbage removed in terms of weight. The examiner should either visit the area before it is grazed or part of it should be protected for comparison. Training for this method requires the examiner to clip vegetation in small amounts and estimate what has been removed. This is useful in estimating utilization that is not always uniform. The method is not easy to use because plant species distribute their weights differently.

Plotless Methods

There are four methods that are called plotless or variable plot methods. They were documented by Cottam and Curtis and Greig-Smith (Mueller-Dombois and Ellenburg 1974).

Closest Individual

In the closest individual method, points are randomly selected along a line transect. Distance from each point to the plant nearest to it is taken. The mean distance for all the plants is equal to half the square root of the mean area (NRC 1962; Mueller-Dombois and Ellenburg 1974).

Nearest Neighbour

In the nearest neighbour method, sampling points are selected along a line transect and from each point plants are randomly selected. The distances from randomly selected plants to their nearest neighbour are taken. The mean distance is equal to the square root of the mean divided by 1.67 (NRC 1962; Mueller-Dombois and Ellenburg 1974).

Random Pairs

From a sampling point a line is taken to the nearest plant and a 90° exclusion angle is set out on either side of it for the random pairs method. The distance from the second tree that is nearest to the first one and lying outside the exclusion angle is taken. The mean distance from all the points is equal to the square root of the mean area divided by 0.8 (NRC 1962; Mueller-Dombois 1974).

Point Centred Quarter (PCQ)

The point centred quarter method was developed by the Wisconsin Plant Ecology Laboratory and later improved by Curtis (Mueller-Dombois and Ellenburg 1974). The method was primarily developed for measuring the tree layer of the plant community. The technique is based on the idea that the number of trees per unit area can be calculated from the average distance between trees.

Sampling points are randomly located along a line transect and from each point four quarters are established (NRC 1962). The distance from the plant nearest to the point in each quarter is then measured. The mean distance is used to calculate the mean area occupied by each tree.

Table 1. Sample PCQ method of measuring distances.

Sampling point	Number of quarter	Distance (m)
1	1	8
	2	5
	3	11
	4	7
2	1	6
	2	15
	3	2
	4	10
Total		64

Mean distance = 64 ÷ 8 = 8 m
Mean area per tree 8 x 8 = 64 m^2
Tree density per hectare = 10000 ÷ 64 = 156 trees

Curtis argued that it is easier to estimate the number of individuals using mean distance rather than the standard way of counting all plants appearing in a quadrat or plot. The PCQ method saves time because it is easier to measure the distances rather than plot boundaries (Table 1).

The accuracy increases with the increasing number of sampling points. Newson and Dix found in 1968 two limitations with this method (Mueller-Dombois and Ellenburg 1974). These limitations were (a) an individual must be located in each quarter and (b) an individual must not be measured twice. Risser and Zedler in Wisconsin and Olang and Peden (1982) found one more limitation: (c) the method overestimates regularly spaced individuals by 100% and underestimates dumped vegetation by 50%.

Bitterlich (Variable Radius) Method

The Bitterlich (variable radius) method was developed to determine the basal area of trees. It was used in 1957 to measure shrub density and again in

1960 to measure tufted grasses (NRC 1962). The method is also used to measure crown cover of trees (Mueller-Dombois and Ellenburg 1974). Crown spread of each tree should be seen so that the measurement can be taken.

A stick with a 30 inch arm and a 3-inch cross arm radius is used. The area subscribed by the small arm is 1% of the area subscribed by the big arm. The area of the small arm is $3 \times 3 \times \pi$; area of big arm, $30 \times 30 \times \pi$; percent of small over big $(3 \times 3 \times \pi)/(30 \times 30 \pi) = 1/100$. When using it a bit is counted when the small arm is either smaller than the tree trunk or crown spread.

Site Potential Approach Method

The site potential approach method was developed by Humphrey (Pratt and Gwynne 1977) and it emphasizes the potential forage production. The criteria for the classification are the contribution of key species of known forage value, plant vigour, seed production, and the occurrence of soil erosion. Heady (1960) followed a suggestion by Brown who favoured increasers, decreasers, and invaders and he suggested four successive stages due to grazing intensity. The first stage is the tall bunch grass climax followed by the intermediate stage of creeping species and the third stage is where the annual grasses are important. The fourth stage is made up of annual broad-leaved herbs with bare and eroding soil.

The site potential approach is recommended for areas that are being managed for a specific group of animals. Skovlin (1971) stated that rangeland characteristics for evaluating conditions are based on: (a) forage plant composition, (b) bush overstory, (c) elements of ground cover, and (d) soil stability. These four characteristics are rated and scored from 1 to 5. The total rating ranges from 4 to 20 and the condition rating is, therefore: 16-20, excellent; 11-15, good; 6-10, fair; and 1-5, poor.

Landsat Imagery

Because of the vast range areas that have very little development in terms of roads and communication, the landsat imagery interpretation method is quite suitable. The method is actually a modified version of the area sampling frame method (Wigton and Borman 1978). Landsat imagery interpretation was also used in Tanzania to collect data for rural development planning (Dunford et al.1983).

Enhanced imagery of a false colour at a scale of 1:250,000 is preferred because contrast is increased between different colours. The method is used in stages (Olang 1983a). The first stage is visual interpretation of landsat imagery into different strata. Stratification is done on an overlay that is later transferred onto a topographic survey map of the same scale as the landsat imagery. Using artifically constructed and natural features like roads and rivers, each stratum is further subdivided into primary sampling units (PSU).

All PSU having the same colour tone are given the same number for random selection of sampling units (SU). The number of SU selected for sampling depends on the time and money available for work. A topographical map is used for orientation purposes and for navigating to the site. The same sites can be revisited if another sampling is necessary. It has been found that different plant communities can register different tones either because of different plant density or composition (Olang 1983a).

The second stage involves the location of a sampling site within a sampling unit that has been randomly selected and is a critical phase in the whole sampling methodology. The site should be located in a representative area, i.e., at least 500 m away from a road and away from any watering point.

Using the overlay and topographic survey map the researcher can drive or walk to one of the sampling units. Once within the unit, the researcher should decide on which direction to move and for how many meters. Next, the starting point for the transect line should be fixed for monitoring purposes, a sampling site should be permanently fixed. A 15-inch concrete beacon dug into the ground and only 1 or 2 inches left above ground has been found useful for marking permanent transects. They should have small metal rods inside so that relocation can be done with a magnetic instrument. The direction or the bearing of the transect should also be recorded.

SAMPLING TECHNIQUE

The major aim of sampling vegetation is to measure changes in plant production, composition, and cover. Because vegetation is in two main layers, the herb layer and the woody layer, two different methods are required for measuring them. Small plots are required for sampling small herbaceous plants and large plots for shrubs and trees (Olang and Peden 1982). Quadrat plots of 0.5 m^2 have been found useful for herbaceous layer measurement, while circular plots of 2.5 m radius are used for woody layers.

Woody Layer

Circular plots of 2.5 m radius are circumscribed along a fixed permanent transect. Random numbers used in placing the plots are permanently recorded for future monitoring. Plant density is used in determining plot size, although in Kenya 2.5 m radius plots have always been used, which means more work in dense stands. From each plot plants are recorded by species and measurements of stem diameter, total tree height, crown depth, and crown spread are recorded (Olang and Peden 1982). Tree density is recorded according to height classes, i.e., 0.7-2 m, 2-4 m, 4-6 m, 6-8 m, and above 8 m. All measurements are recorded in a field data sheet. The information is later analyzed using a computer.

The need to learn about the woody layer cover is made more urgent by the increasing demand for charcoal and woodfuel. It is, therefore, necessary to determine the aboveground biomass (Olang 1984). Change in crown cover may not occur if one species is replaced by another. It is, therefore, important that plant composition should be measured, so that change can be detected.

Herb Layer

Herbaceous plants form the major food source for herbivores, which necessitates determining their quantity and quality. The method calls for ocular estimation of plant cover within 0.5 x 0.5 m quadrats or any other plot size depending on plant density. Random numbers are chosen between 15 and 25 m and these are used to place up to 40 quadrats. Thus, an area of about 800 m is covered when sampling herb layers from one site. This eliminates some localized effects like an old boma site or a swamp from influencing the collected data.

All plants in a quadrat are listed by species then the percentage ground cover by plant foliage is estimated visually. Estimates are first done on 50% of the quadrat, then on 25%, and last on 10% of the quadrat. Those that do not make 1% are recorded as trace. The weight of all plants in the quadrat is estimated and recorded then plants from 25% of all quadrats are clipped and weighed. The clipped material is later oven-dried and then weighed. The weight of the material from the clipped quadrats is later extrapolated for the rest of the quadrats.

A combination of the list quadrat method, discussed earlier, for herbaceous plants and circular plots for woody plants is being used by KREMU (Olang 1983b) to detect changes in plant composition, cover, vigour, production, and density.

All woody plants are recorded within a 2.5 m radius segment along a 100 m transect. Herbaceous plants are recorded at 10 m intervals. Because the transect line is permanently fixed with a beacon and the bearing is also known, later measurements on the same plants can be done easily.

Most of the methods can be used to measure plant composition, density, cover, and production. Periodic measurements of the same sites are used to measure changes in the various parameters measured, e.g., whether certain plants are in danger of extinction, loss of vigour, or possible reduction of their crown cover. What is important is that the transect is permanent. Skovlin (1980) reported on seven botanical methods studied in Zimbabwe, the line intercept method was recommended as suitable for cover analysis, while the plot frequency method is suitable for measuring change in the composition of important species. Pratt and Gwynne (1977) suggested a rating system where the condition of an area is expressed according to a scale ranging from excellent to very poor. It combines desirability scoring for plant composition changes. Skovlin (1980) used it to measure vegetation changes in Kenya's rangeland. The International Livestock Centre for Africa (ILCA) has used permanent point loop transect for herbaceous vegetation and belt transect for woody species in Kenya (Bille and Heemstra 1978).

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AUSTRALIAN-SOUTHEAST ASIAN AND PACIFIC FORAGE RESEARCH NETWORK

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Abstract *Pasture research workers in Southeast Asia and the Pacific face many constraints in the development of effective research programs. Opportunities for discussion of problems of mutual interest are few both between scientists in the different countries and experienced scientists elsewhere. Access to scientific and technological information is limited. The paper discusses these and other constraints and the opportunities for overcoming them, through the function of a Network established to link pasture/forage scientists in the region. The major objective of the Network is to improve the effectiveness of research and forge strong interactive links between scientists and extension workers in the countries involved for the benefit of improving livestock production and income of primary producers in the region.*

The objectives of agricultural research in most, if not all, developing countries are primarily to solve problems concerned with improving the nutritional levels and reliability of food supplies for their populations. Staple food crops are given the highest priority in research, but the improvement of ruminant livestock production is also considered important. The reasons are varied; in the more affluent developing nations as Gross National Product (GNP) increases and more money becomes available to their people, the demand for meat increases; in the poorer nations, there is a demand for increase in meat and milk not only to provide improved nutrition for the existing population but to meet the demands from an increasing population. In many cultures, large ruminants are a source of draft power for crop productivity and manure for fertilizing such crops. There are also socioeconomic reasons for being able to maintain or improve livestock populations, for example, they are a source of capital for use in times of hardship.

Although food-crop production receives a greater emphasis in improving food supplies, a combination of crop and livestock in farming systems can have a major impact in improving overall productivity. Ruminants make a particular contribution to improving the efficient use of land resources, through their ability to utilize crop residues and by-products not suitable for human consumption and to use pastures or forages on land not suitable for crop production.

These resources cannot be fully utilized or improved in productive capacity without appropriate research involving a range of scientific disciplines. Interactions between climate, soil, plant, and animal and the effect of human interference in this dynamic biological system are highly complex. For research to be fully effective, there is "conceptually" a requirement for a "critical mass" of scientists from different disciplines that is necessary to sustain any serious research effort. This concept is applicable in both developed and developing nations, but is more difficult to put into operation in the latter. Limited financial resources and shortage of scientists and technical personnel are a serious constraint to achievement in research. Isolation of scientists either geographically or through lack of contact with their peers in their own or other interactive disciplines and inadequate support services are also important constraints.

The establishment of a network of pasture/forage scientists would provide a means of overcoming some of these problems and give support and encouragement to scientists in developing countries. Expertise from within the network could aid in identifying priorities in research and provide a sound basis for requests for resources to undertake research in high-priority areas. It should be recognized that agricultural scientists not only have a responsibility to provide information to farmers, which is used to plan and implement improved production of crops and livestock, but also to provide reliable information to governments for future planning of development policies. It is important, therefore, to develop a cadre of competent scientists capable of problem solving and of interpreting national and international scientific advances for the benefit of national development.

PASTURE/FORAGE NETWORK IN SOUTHEAST ASIA AND THE PACIFIC

The Australian Centre for International Agricultural Research (ACIAR) and the Australian Development Assistance Bureau (ADAB) are jointly supporting the establishment of a Network of Pasture/Forage Scientists in Southeast Asia and the Western Pacific. The background to this project is as follows.

Australia has had a substantial effort on tropical pasture research for some 30 years and is in a strong position to assist pasture research in the Asia-Pacific region. For more than 10 years, Australian scientists have been involved in pasture research in collaboration with local scientists in the Asia-Pacific region, especially in the Southeast Asian countries of Indonesia, Malaysia, and Thailand. During this period, there has been substantial growth in interest in pasture investigations by national institutions and universities within the region. The development of improved pastures and other aspects of livestock production has also been encouraged through bilateral and multilateral aid programs in which Australia has taken a leading part.

The growing interest in pasture and forage production and its utilization by ruminant animals has been reflected in a considerable increase in the number of scientists and research centres active in these fields. However, much of this research is at an early stage of development and local experience in planning and conduct of research programs, interpretation of results, and in experimental techniques is limited. Pasture workers in these Asia-Pacific countries are handicapped by lack of regular access to information on relevant developments. Opportunities for discussion of problems of mutual interest are few, both between scientists in the different developing countries and between them and experienced tropical pasture scientists in Australia. There has been an increasing desire by scientists in the region for better communication and contact both between themselves and with Australian scientists; the establishment of a network is perceived as a means of meeting this need.

Countries working in pasture/forage research in Southeast Asia include the Philippines, Thailand, Malaysia, and Indonesia and Fiji in the western Pacific; selected statistics are shown in Table 1. The land area of 297 x 10^6 ha carries a human population of some 269 x 10^6 people of whom approximately 58% are involved in agriculture. Ruminant populations are approximately 13.6 x 10^6 cattle, 11.8 x 10^6 buffalo, 4.3 x 10^6 sheep, and 10.3 x 10^6 goats. Small ruminants are kept for meat production, but both cattle and buffalo are primarily used for draft purposes and ultimately for meat, when they are too old to work.

The region has climatic diversity, even within countries, due to monsoon influences and marked topographic effects. Similarities exist between eastern Indonesia, northeast Thailand, and the western parts of Luzon and Visayas in the Philippines where there are distinct wet and dry seasons. In contrast, west Indonesia, southwest Thailand, Malaysia, the eastern Philippines, and Fiji have a short (2-3 months) dry season or no period without rain. There are also transitional zones with generally higher rainfall variability than either of the above. The range of annual rainfall reported from within the region is from 570 to more than 7,000 mm.

The problems of increasing forage/pasture production to meet ruminant requirements are intensified in some areas through the combination of intensive land use for cropping with high human and ruminant populations. The most extreme case is in Java and Madura in Indonesia. These islands carry 64% of the human population of Indonesia together with 60% of the cattle, 43% of the buffalo, 80% of the goat, and 94% of the sheep. In this highly fertile and intensively cropped area, large ruminants are being replaced with small ones because of first, the diminishing crop area per family and uneconomical animal use of cattle/buffalo for

Table 1. Selected statistics for countries participating in the Forage Network.

	Philippines 4°N-21°N	Thailand 3°N-22°N	Malaysia 10°N-6°N	Indonesia 11°S-6°N	Fiji 16°S-19°S
Land area (ha x 10^6)	29.8	51.3	32.8	181.1	1.83
Human population (x 10^6)	51.9	49.2	14.8	153.0	0.65
% in agriculture	44.6	74.4	46.2	57.8	38.70
Ruminant population (x 10^6)					
Cattle	1.95	4.50	0.55	6.4	0.16
Buffalo	2.80	6.20	0.29	2.5	na[a]
Sheep	0.03	0.02	0.07	4.2	na
Goats	1.60	0.32	0.38	8.0	

[a] na = not available

Source: FAO Production Yearbook, 1982.

cultivation and, second, the greater flexibilty in feed and financial management offered by sheep/goats. The average number of cattle per family is 1.8 and food supply for them is dependant on crop residues, cut forage from waste areas, back gardens, roadsides, or plantation crop areas. In contrast, Indonesia also has an estimated 19 x 10^6 ha of *Imperata* grasslands that could be improved for animal production and are currently almost unused.

There are three broad areas that require research for improving pasture/forage production:

(a) Backyard or smallholder farms. Although 90% of the ruminant population in the region is owned by smallholders, most are confined to the family farm area. This may vary from 1-5 ha. Improvement in forage production is being undertaken by use of forage tree legumes, e.g., leucaena, and the more vigorously growing grasses such as Napier grass.

(b) Extensive native pasture lands, often on soils of low fertility and with a pronounced dry season. Some of these are common grazing lands that present special problems in species establishment and management.

(c) Use of forages in intercropping systems. An obvious target area is use of pastures/forages under plantation crops, e.g., rubber, oil palm, coconuts, and reafforestation areas. Another is intercropping with forage species in a cropping system. For example, undersowing a legume in the later growing stage of rice production, or as an alternate crop after rice; both techniques are being researched in Thailand and the Philippines.

CONSTRAINTS IN RESEARCH

The introductory statement in this paper mentioned some constraints that apply in the Southeast Asia/ Pacific region as well as to developing countries in other regions. Other than financial constraints in research funding, the most serious one is probably inexperience by scientists in research planning. Research in soil-plant-animal-systems requires interaction between scientists of different disciplines. The team should ideally comprise scientists with expertise in the fields of pasture agronomy, plant nutrition, legume bacteriology, soil science, animal nutrition, and biometrics. A range of such expertise within individual countries may exist but there are often no integrated research programs involving such disciplines. In other instances there may be no experienced scientists available in some disciplines.

The lack of interaction between plant and animal scientists is cause for concern. This dichotomy of interest is partly historical and was a considerable problem in some developed countries for many years. Animal scientists, many with a veterinary background, tend to place a higher priority on animal health and genetics than on improving the nutritional status of animal feed supplies. Both health and genetics require research, but it is well documented that a well fed animal is more resistant to (or tolerant of) pests and diseases and that the genetic potential for growth and production cannot be fully expressed on poor-quality feeds.

COMMUNICATION CONSTRAINTS

Communication is an integral part of research and this includes obtaining scientific and technological information from existing world agricultural knowledge. Adequate library services play an essential part in this information flow, but in many instances their capacity to provide these services is limited. Journals from both international and in-country sources are just not available. Although a literature review is a standard requirement for planning experiments, available resources often preclude this.

One of the most productive channels of information from outside a country are networks that link persons in the same lines of research. These contacts may be made through attendance at workshops or conferences, but these opportunities are limited to only a few scientists in the region.

Communication of research information to end-users could be greatly improved. Liaison between research institutions and extension workers is often poor, partly because there are no formal linkages between departments with these responsibilities.

OBJECTIVES OF THE AUSTRALIAN-SOUTHEAST ASIAN PACIFIC NETWORK

The broad aim of the Network is to improve the effectiveness of research in the participating countries by providing support and encouragement in research and to aid in overcoming communication problems. Specific objectives are:

(a) To help improve the individual countries' capacities to plan research programs that are of high priority in achieving the countries' objectives;

(b) To encourage each country to undertake discrete programs of research that are of mutual interest to participating countries;

(c) To strengthen technological capacity at all levels;

(d) To strengthen each country's information base;

(e) To help provide for the extension of research developments through regional, national, and local channels and their application at the farm level;

(f) To develop a network that will provide a substantial base for long-term future contacts between regional scientists.

Structure and Composition

There are a substantial number of scientists in the Southeast Asia-Pacific region who have some interest and activity in pasture/forage research. In the initial stages of developing the Network, it is considered that the greatest impact would be achieved by establishing a Primary Network of some 10 leading scientists, actively undertaking research, as core members. These scientists would act as focal points for dissemination of the benefits arising from Network activities to other workers in their country or region. Members of the Primary Network would be those institutions actively engaged in pasture and fodder research on a significant scale whose staff and facilities are of a quality that enable them to derive most benefit from and contribute to core Network activities.

The countries with such a capacity are the Philippines, Thailand, Malaysia, Indonesia, and Fiji. Other countries in the region that have no national institution or scientists working in pasture/forage production are unable at this point to be core members. However, this does not mean exclusion from Network functions that could help in the development and utilization of pastures/forages for ruminant production.

Network Function

(a) To provide comment and assistance in planning research and its execution. This function includes assistance with experimental design, choice of appropriate techniques, and advice on the selection and purchase of equipment and consumables for use in experimental programs.

(b) To provide guidelines and advice to scientists on the interpretation and publication of research results.

(c) To identify training requirements at both the scientist and technician levels and to implement training programs.

(d) To assist and encourage pasture/forage seed production and distribution.

(e) To strengthen communication and information bases in the region by: publishing a newsletter 3-4 times a year informing pasture and forage scientists in the region about research activities in the region and their results. It would provide a medium for publication for workers in countries where there are no appropriate local journals. Results of studies of interest to workers in the field, but not acceptable to internationally recognized journals (e.g., results from initial screening of pasture species) would be included, as well as abstracts and comments on developments of particular interest in pasture science. The newsletter would be widely distributed to all interested pasture scientists in the region.

(f) Arranging annual workshops for members of the Primary Network the venue would rotate between member countries. It is planned to invite other scientists and senior extension persons to attend, but to be effective a workshop should not include more than about 20 persons.

(g) To establish a computerized data base to provide information on (a) scientists in the region and their research and (b) published literature from the region and from conferences and workshops that do not formally publish proceedings.

The Network needs the backing of a research institute with experience in tropical pasture research. The CSIRO Division of Tropical Crops and Pastures has accepted responsibility for the Network and to make available the Scientific Secretary. The Division has research staff with a great deal of accumulated experience in pasture agronomy and ecology and animal production, plus specialists in plant breeding and adaptation, plant nutrition, nitrogen economy of pastures, legume bacteriology, plant physiology, plant biochemistry, animal nutrition, and forage genetic resources. Other scientists in northern Australia with experience in these and other fields would be called on by the Network for information and advice on specific research or extension problems as necessary.

It is hoped that the Network will not only improve the effectiveness of research, but forge strong interactive links between scientists and extension workers in the countries involved and make a substantial impact on improving livestock production and the income of the primary producers in the region.

NETWORK APPROACH IN PASTURE RESEARCH: TROPICAL AMERICAN EXPERIENCE

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Abstract *Animal production and productivity are A slow in tropical America in spite of its large number of cattle. The main constraint for animal production is the availability and quality of pastures. Considerable efforts have been spent on pastures research. However, its impact has been rare. Pasture research is a long and costly endeavour. At the same time, resources for research are becoming more scarce. Faster and more economical ways have to be found to solve these problems. The network approach and the orientation of national pasture research programs could provide alternatives. The paper presents an overview of pastures research experiences, the activities of the International Tropical Pastures Network in Latin America and a scheme for an applied pasture research program.*

Animal production and productivity in the tropical areas of Latin America are low compared to what is found in temperate areas (Table 1). As a result, large deficits of beef and milk are found in most of the region. The difference between the growth rates of beef demand and production for tropical America in the last 10 years has been 3.1%/year. Surpluses, however, occur in some temperate American countries (Table 2).

Vast areas of acid infertile soils (oxisols and ultisols) account for 40-50% of the total land resources. In these regions, current stocking rates are as low as

Table 1. Livestock population and animal productivity in the USA and selected countries of Latin America, 1981.

Region/country	Population (10^6 cattle)	Productivity (kg/animal/year)
United States	114	90
Tropical America	199	24
Brazil	93	24
Colombia	24	24
Venezuela	11	31
Temperate Latin America	69	52
Latin America	267	31

Source: CIAT (1983).

Table 2. Beef: annual growth rates of demand and production in Latin American countries.

Region/country	Growth rates (%)	
	Demand	Production
Tropical America	5.3	2.2
Bolivia	4.9	4.9
Brazil	6.1	1.5
Colombia	4.9	3.5
Dominican Republic	6.0	3.4
Ecuador	8.9	5.3
Mexico	4.4	3.3
Paraguay	4.4	-1.1
Peru	3.0	-1.3
Venezuela	4.2	5.4
Central America	4.0	3.3
Caribbean	3.2	2.0
Temperate Latin America	1.7	3.2

Source: CIAT (1983).

0.12 animals/ha. These areas have great potential for agricultural production, because they receive ample solar radiation and, in general, have good physical soil properties and extended growing seasons. On these soils, low quality and quantity of available forage are the most important constraints for beef and milk production.

In some cases, dry matter availability (quantity) is not as limiting as it is in the extensive grasslands in the subhumid savannas (llanos of Colombia and Venezuela and cerrados of Brazil), where grasses grow rapidly and profusely after burning. Although cattle graze the young regrowth for 2-3 months, the available forage soon becomes unpalatable and accumulates as fuel for the next burn. Farmers traditionally burn different areas in a sequential pattern utilizing the same area every 18-24 months.

In contrast, under the much more intensive resource utilization (land, animals, feeds, etc.) that occurs in dual-purpose cattle production systems under the more humid environments of tropical America, both quality and quantity are extremely important. Land is more expensive and higher costs (land clearing) are required for establishment of crops or pastures. Maintenance costs are also expensive due to the need to control weed invasion and amendments and fertilizers required to maintain productivity. Often pasture degradation occurs rapidly while the farmer's herd naturally grows. This creates unbalanced situations where dry matter availability and higher carrying capacity of pastures become more important.

These two contrasting situations obviously require different and very specific research approaches. In the first case, grasses and legumes under minimum management should maintain quality and productivity for cattle in a relatively low-stocking rate farming system. In the second case, in the humid tropics dual-purpose system, improved grasses and legumes and better options for management should make higher stocking rates and controlled weed competition possible, thus providing better distribution of forage throughout the year.

In addition to the farming systems, pasture components (grasses and legumes) should be expected to be different under the variable complexes of soil, climate, diseases, and pest pressures that occur in different environments. The use of available (commercial) pasture species in different environments commonly results in a failure at the adoption level. These differences occur across countries, across regions within countries, as well as across farms in the same region.

Considerable resources and effort are being spent on pasture research. However, quite often the impact of the utilization of research results has been rare. Contributing factors to this situation have been lack of definition of target agroecosystems, lack of representativity of research station locations, fragmentary research efforts, lack of farmers' involvement, inadequate links between research, and transfer of technology.

Resources for research in the developing world are becoming increasingly limited, and pressure for obtaining rapid answers to animal production systems problems is also increasing. The need to find more economical and faster ways in pasture research utilizing local and regional expertise is most necessary. The network approach can provide an alternative for the integration and complementing of national pasture program efforts, thus reducing costs and time and, at the same time, improving the coverage of the extremely complex combinations of environmental and farming system situations.

This paper presents an overview of pasture research experiences in tropical America, a description of the Latin American Tropical Pastures Network, and some suggestions for research schemes in national pastures research programs.

PASTURE RESEARCH EXPERIENCES IN TROPICAL AMERICA

To evaluate the emphasis and volume of research on tropical pastures in tropical America, a computerized catalogue of the 3,170 summaries (CIAT 1979, 1980, 1981, 1982, 1983) was done. This is a specialized publication including most scientific and monographic articles about tropical pastures published in English, Spanish, and Portuguese.

Publications of Latin American scientists are not very well known in the international scientific community. One of the reasons for this is language; most publications in the region are in Spanish or Portuguese. However, their prolificacy and contribution to the subject of tropical pastures are quite substantial with 1,034 articles from countries of tropical America (Brazil, Colombia, Venezuela, Peru, Cuba, etc.), compared with 161 from the USA, and 516 from Australia and New Zealand, and 1,459 from other countries.

Comparing the number of papers by research subject in the total vs. tropical America (Table 3), it is important to note that although the proportion of papers on soil microbiology and pasture management and productivity is about the same in the region as in the total, in tropical America, there is less research emphasis on plant physiology, animal nutrition, pasture quality and productivity, farming systems, and economics research. However, there is a major research emphasis on the subjects of germ plasm and genetics, plant protection, agronomy, soils, and fertilization, as well as on seed production.

This tropical American major emphasis on agronomic work perhaps depicts the excessive concentration of pasture research in small plot evaluations under cutting that occurs normally in less-advanced or incipient pasture research groups. However, the emphasis on fertilization trials and on plant protection seems well justified by the needs of research on the predominantly acid infertile soils and on the high pressures of pests (Cigarrinha, Mion or Salivazo),[1] as well, as diseases (anthracnose in Stylosanthes spp., rhizoctonia, bacteriosis, and cercospora in Centrosema spp., etc.) that occur in tropical America.

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[1] Sucking Homoptera of the genera Zulia, Aneolamia, Mahanarva, etc., that severely affect grasses, especially Brachiaria spp.

Table 3. Publications in different fields of tropical pastures research.

Field	Total No.	Total %	Tropical America No.	Tropical America %
Germ plasm and genetics	242	7.6	95	9.2
Plant physiology	130	4.1	31	3.0
Plant protection	146	4.6	76	7.4
Agronomy	324	10.2	138	13.3
Soil fertility	509	16.1	222	21.5
Soil microbiology	179	5.6	53	5.0
Pasture establishment	110	3.5	51	4.9
Animal nutrition	458	14.4	99	9.6
Pasture quality and productivity	416	13.1	39	3.8
Pasture management and productivity	327	10.3	105	10.2
Seed production	223	7.0	106	10.3
Farming systems and economics	106	3.3	19	1.8

In the same way, Table 4 shows the contribution of tropical America and that of the total based on monographic publications on small plots under clipping and those on grazing and pasture animal-production work. Although the monographic contribution of tropical America is about the same as the total, very clearly the proportion of research publications on small plots under clipping increases at the expense of publications on grazing and pasture-animal production work for the case of tropical America.

Table 5 shows the distribution of published work in tropical pastures according to type of cattle enterprise. It is evident that most published work has been conducted on beef production; a lower proportion on milk production and a minor one on dairy-beef dual-purpose production. These proportions contrast with the predominance of the dual-purpose farming system, and the importance of milk production in a region where most countries are importers of that commodity. This clearly indicates the degree of initial development of

Table 4. Publications by different levels of tropical pasture research.

Level of evaluation	Total No	Total %	Tropical America No	Tropical America %
Monographs	451	14.2	139	13.4
Agronomic small plots under clipping	2055	64.8	828	80.0
Grazing effect	197	6.2	49	4.7
Pasture-animal productivity	359	11.3	13	1.3
Use of supplement feeds	108	3.4	5	0.4

Table 5. Published data on tropical pasture evaluation under grazing according to animal production systems.

	Animal production systems		
Country and regions	Beef	Milk	Dual purpose
Brazil	79	7	1
Colombia	49	5	-
Cuba	28	44	1
Peru	4	-	-
United States	18	2	-
Venezuela	4	3	1
Rest of America	76	13	7
Other countries	66	6	1
America with acid soils	163	59	3
New Zealand and Australia	99	15	1

tropical pastures research activities in tropical America, as well as the lack of experience of researchers and adequate funding from Latin American research organizations to undertake grazing work at early evaluation stages.

INTERNATIONAL TROPICAL PASTURES EVALUATION NETWORK (RIEPT)

In cooperation with national pasture research programs in tropical America, in 1978, the Tropical Pastures Program of the Centro Internacional de Agricultura Tropical (CIAT) was the catalyst in the formation and organization of RIEPT, with the following main objectives: (a) germ-plasm introduction and evaluation, (b) development of appropriate and simple methodologies for pasture research, (c) exchange of information, and (d) training. In 1979, as a result of the first meeting (workshop) of collaborating institutions (Table 6), there was agreement on the basis of organization of the network (Toledo 1982) as well as on the methodological evaluation sequence to mobilize effectively new germ plasm (from national program sources and CIAT) throughout the region and from the initial introduction gardens to grazing trials and farming systems.

The common failure of commercially available cultivars (selected under different environments) in the highly acid infertile soils and under high disease and pest pressures that predominate in tropical America was clearly recognized. The diversity of ecosystems and farming systems requiring new improved pastures was also very clear.

Sequential Methodology of Evaluation

Based on the common interest of testing new germ-plasm options, four types of multilocational trials were conceived. First, regional trial A (RT-A) to evaluate survival of a large number of entries (100-150) in a few highly representative sites in major ecosystems and, second, regional trial B (RT-B) established in as many sites as possible to measure seasonal dry matter productivity of a reduced number of promising entries (20-30) selected from RT-A and major screening sites of national programs and CIAT. These first two types of regional trials are agronomic, utilizing uniform methodologies (Toledo and Schultze-Kraft 1982) to allow comparisons of germ-plasm performance across locations to study the range of adaptation to basic environmental parameters (soils, climate, and biotic factors).

Table 6. List of institutions by countries participating in the first workshop of the RIEPT (October 1979).

Country	Institution
Australia	CSIRO
Bolivia	Centro de Investigación Agricola Tropical
Brazil	CEPLAC-Bahía
	CIAT/CPAC-Brasilia
	EMAPA-Maranhao
	EMBRAPA-Brasilia
	EMBRAPA/CENARGEN-Brasilia
	EMBRAPA/CNPGC-Mato Grosso
	EMBRAPA/CNPGL-Minas Gerais
	EMBRAPA/CPAC-Brasilia
	EMBRAPA/CPATU-Pará
	EMGOPA-Goiás
	EPAMIG-Minas Gerais
	FAO/UEPAE-Teresina, Piaui
	IAPAR-Paraná
Colombia	CENICAFE
	CIAT
	Fondo Ganadero del Putumayo
	ICA
Cuba	Instituto de Ciencia Animal
	Ministerio de Agricultura
Ecuador	Escuela Superior Politécnica de Chimborazo
	INIAP
Guyana	Livestock Development Co. Ltd.
	Ministry of Agriculture
Jamaica	Ministry of Agriculture
Mexico	INIA
Nicaragua	INTA (MIDINRA)

(continued)

Table 6. Concluded.

Country	Institution
Peru	COPERHOLTA-Tarapoto
	INIA/CTA-Tarapoto
	INIA/NCSU-Yurimaguas
	IVITA-Pucallpa
	Universidad Agraria "La Molina"-Tarapoto
Surinam	Ministry of Agriculture
Trinidad	Ministry of Agriculture
Venezuela	Centro Nacional de Investigaciones Agropecuarias
	FONAIAP
	FUSAGRI
	Universidad Central de Venezuela
	Universidad de Oriente
	Universidad del Zulia

Third, regional trial C (RT-C) to evaluate under grazing a further reduced number of accessions (about 10) assembed in grass-legume mixtures. The purpose of these trials is to assess the dynamics of the sward in terms of productivity (carrying capacity of dry matter on offer), and botanical composition (proportion and survival of grass and legume), under different intensities and frequencies of grazing. Regional trial Cs in small plots under grazing are conducted with different designs only at relatively few sites of the network because most of the generated information in terms of grass-legume compatibility and effect of trampling may be considered as highly dependent on the genetic characteristic of the plants and could be extrapolated to animal productivity trials (Paladines and Lascano 1983).

Fourth, regional trial D (RT-D) assesses pasture productivity and persistence in terms of animal products (animal body weight gains, milk production, etc.) of the best new pastures compared with the best traditional pastures used in the region. It is expected that the management commonly used in the prevailing farming system should be incorporated in the treatments and design of these trials. Consequently, it is expected that RT-Ds will be conducted using independent methodologies and in as many locations as possible because they must aim to improve existing pastures in the predominant farming systems of the area of influence of each location.

Figure 1 shows the organizational scheme of RIEPT, where germ plasm is sequentially passed through the different regional trials in the different ecosystems. The information generated (Pizarro 1983) is shared by all members of the Network by means of direct communication, meetings, workshops, the Tropical Pastures Bulletin (published 3 times a year), and by direct consultation with the central data base of the network located in CIAT. The sequence in several locations is being reduced to the steps RT-B and RT-D, using information of the full sequence generated by other more-developed pasture research groups in locations within the same ecosystem. In a parallel fashion, all national programs are also working with the resulting promising selected materials, especially to study and adjust fertilizer and *Rhizobium* requirements, to develop establishment techniques, and to optimize their performance under the specific soil conditions of the location.

To support this cooperative effort, the Tropical Pasture Program of CIAT, with financial aid from the International Development Research Centre (IDRC), is conducting supportive methodological research especially to modify available techniques and develop new techniques more suited to the conditions (technical and economical resources) of national programs in the region.

The rapid expansion of RIEPT between 1978 and 1983 is shown in Table 7. In 1983, 84% of the trials were at the agronomic level (RT-A and RT-B), and 16% were evaluations under grazing (RT-C and RT-D). At present, several new grazing trials are being proposed and established. Some of these trials are partially financed by IDRC, especially for national programs with less resources. To date, RIEPT has been most instrumental in catalyzing the research activities on

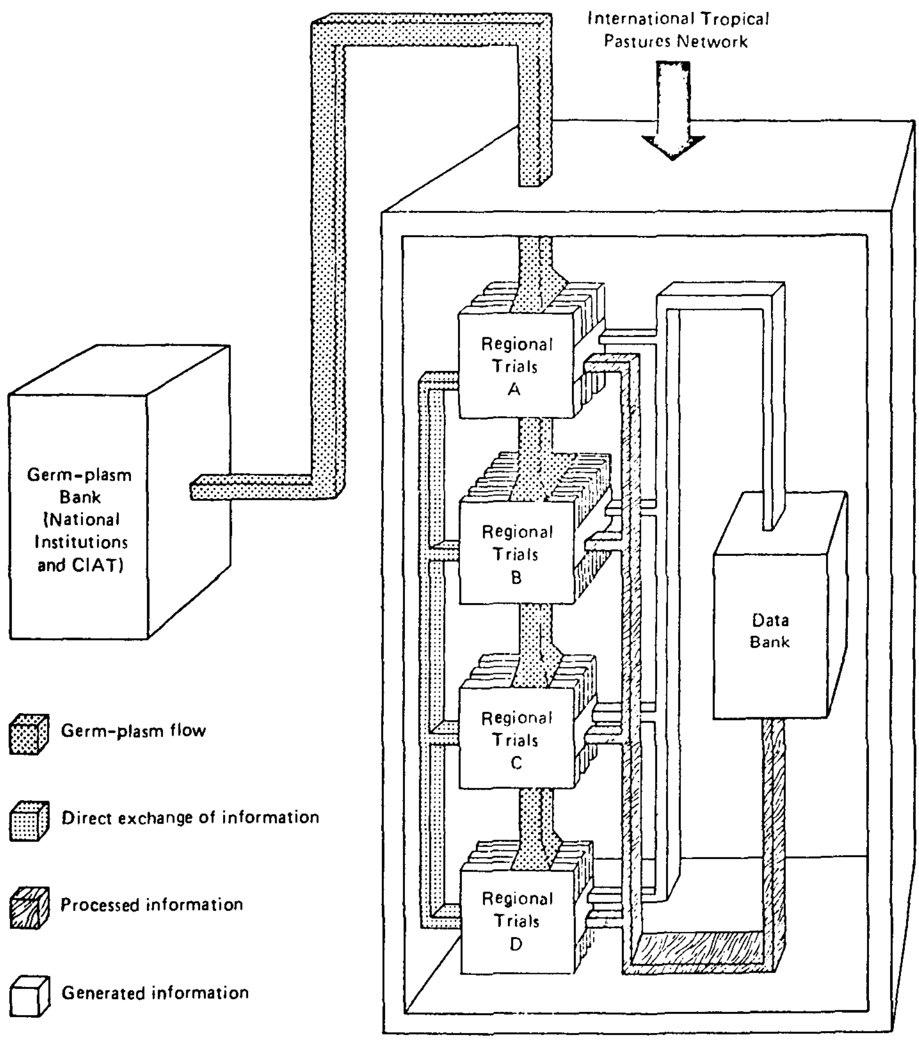

Fig. 1. Organization of the International Tropical Pasture Network.

Table 7. Active[a] regional trials between 1978 and 1983 by countries.

Countries	1978	1979	1980	1981	1982	1983
Bolivia	1	1	1	2	2	2
Brazil	1	8	12	9	9	16
Colombia	3	5	12	11	13	13
Costa Rica	-	-	1	1	1	2
Cuba	1	1	-	-	1	1
Ecuador	2	2	3	3	4	6
Guyana	-	-	2	1	1	-
Hawaii	-	-	1	1	1	-
Honduras	-	-	-	-	-	1
Mexico	-	-	-	1	1	7
Nicaragua	-	-	2	3	3	3
Panama	-	-	3	3	3	10
Paraguay	-	-	-	1	1	-
Peru	3	3	5	7	11	13
Dominican Republic	-	-	-	-	-	4
Trinidad	-	-	1	1	1	-
Venezuela	4	4	5	5	5	-
Total	15	24	48	49	57	78

[a] Active = sown trials reporting information.

tropical pastures in national programs in tropical America and is strongly helping them to advance into grazing evaluation on-station as well as on farms. In this sense, two new initiatives are being undertaken. First, the on-farm evaluation of improved pastures in animal production systems (RT-E) and second, the support to national programs to organized seed-production activities.

SCHEME FOR EFFECTIVE APPLIED RESEARCH ON PASTURES

Commonly, the organization of agricultural research is based on the specialization of the person responsible for its design. Often there is a lack of a comprehensive scheme that will thoroughly incorporate the activities of applied research as well as the participants and their relationships with basic research components in addition to global incorporation within the framework of the target area.

When a research program is set up, often the organizers emphasize disciplinary work: breeding, fertilization, animal nutrition, mechanization, etc., in a scheme of "applied research" that commonly does not give enough attention or consideration to farmers. However, although not as frequently as in the past but certainly more so in recent years, some research programs are organized to emphasize research in farmers' fields strongly, very often only describing and documenting farmers' practices. Nevertheless, the alternatives to solve the basic problems of productivity in rural areas are lacking.

In addition, historically, research and extension have been disconnected, especially in the developing countries. Despite the very elaborate and often very comprehensive diagrams and organigrams put to paper to link these two very important activities for rural development, in reality the link is at most tenuous.

The results (of this comprehension) often produce frustration for researchers and extensionists, new technologies with little potential of adoption by farmers, political discredit of research and extension activities, and reduction of economic support that often destroys or reduces the activities of a program. In this way, large amounts of money, resources, and time could be spent while farmers remain the same with their traditional techniques, low productivity, and poor standard of living.

Scheme for Effective Applied Research

One way to approach the applied research activities more effectively is to consider them as comprehensively as possible, where the activities of researchers, extensionists, farmers, developers, etc., are consolidated in a flow of research activities and information toward more productivity and a better standard of living for farmers.

Figure 2 represents our suggested view of the activities involved in applied research. The basic, natural (soil, climate, and biotic), and socioeconomic

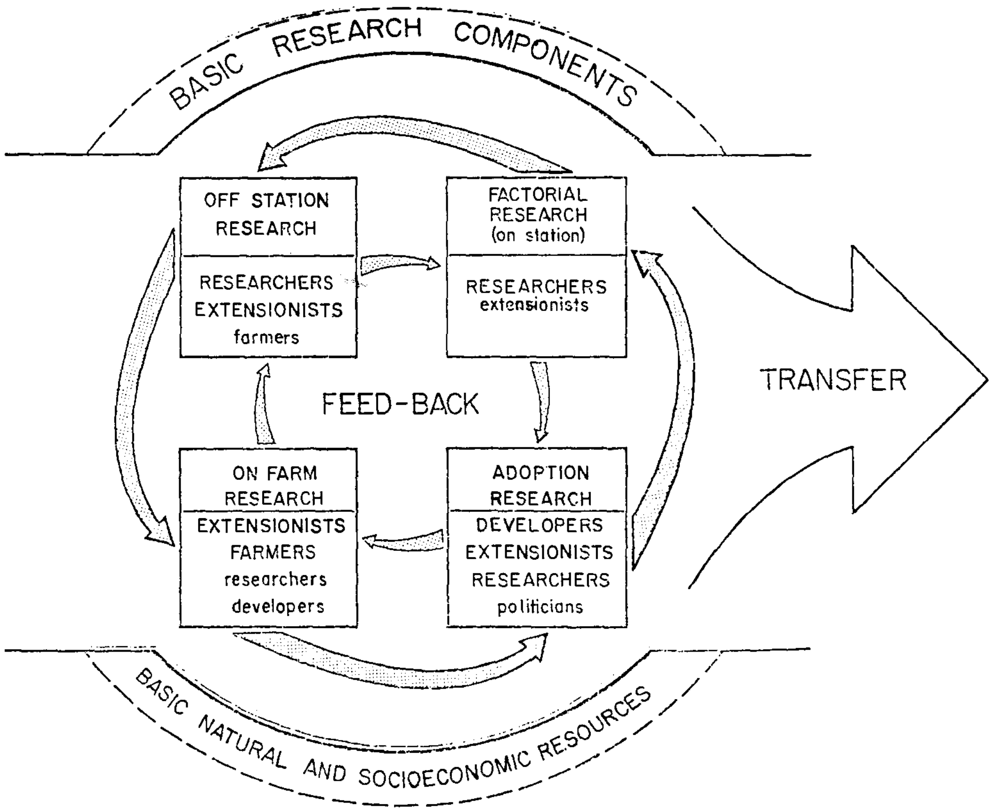

Fig. 2. Organization, participants, and flow of information in an applied research program.

(farming system, anthropologic, economic, etc.) resources (BNSR) have to be evaluated and described at the macrolevel to set the bases for understanding the target area, to set research priorities, etc. Understanding of the ecosystems and prevailing farming and animal production systems is basic for the definition of the applied research programs. Knowledge of the ecosystems in terms of soils, climates, topography, etc., helps in the definition of environmental constraints and the adaptation domains, i.e., confines, (limits for the technology). Farming systems characterization will help in defining the resources (land, animals, crops, type of pastures), management (fertilization, rotations, etc.), products and productivity (milk, beef yields, birth rates, etc.), and all relevant interactions of farm components in the target area. They provide an idea of the production constraints. These research activities are represented at the bottom of Fig. 2 to emphasize information that should be regarded as basic. In the top of the scheme, the basic research components (BRC) are included to emphasize the other available information and resources for applied research. These BRCs are germ plasm, fertilizer sources, means for plant protection, tools, machinery, etc., and normally are developed by other specialized research and/or production organizations. The applied research should consider them basic for the development and assembly of new technology.

For the BRC and the BNSR, the applied research takes place with the objective of combining resources from the two kinds available to optimize and/or modify (positively) the existing production techniques in the prevailing ecosystem and farming system. The applied research covers a range of research activities that includes (a) factorial research (on station), (b) off-station research, (c) on-farm research, and (d) adoption research.

Factorial Research

Factorial research is usually conducted in experimental fields (minor research stations). Its role is very important in selecting from the BRCs the components that suit the needs for the research toward the prevailing farming systems (e.g., major screening of germ plasm, characterization of the performance of performance of promising selections, breeding, management and its interaction with the nonlocation-specific responses of selected materials, use of alternative sources of fertilizers and chemicals).

Other important roles of on-station research are methodological adjustment and development as well as coordinating and centralizing the activities of the whole applied research endeavour. The participants of the factorial research traditionally are only the researchers. However, the coparticipation of researchers and extensionist leaders is of great importance.

Off-Station Research

Commonly, the research station represents only limited and quite often the best[2] conditions of its target area. Off-station research is very important in any applied research program. Its objective is to validate and adjust selected components to different environments (e.g., minor screening of germ plasm (RT-B and RT-C), fertilizer dosage, mineral requirements, management trials and their interactions with location specific responses). In addition to the researchers and extensionists, the participation of at least leading farmers is very important for this multilocational research activity.

On-Farm Research

The specific components and techniques adjusted for the several environmnents of the target area should be validated at the farm level. Usually on a farm, several micro-environmental conditions occur. In addition, each farmer has different experiences, preferences, skills, resources, etc. Consequently, the exposure of the newly generated technology to farmers' management and adaptation is a very important research activity for the final selection of adoptable technology.

The objective of on-farm research is to validate new technologies at the farmer level, evaluating their performance, as well as the modifications and adapta-

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[2] Frequently, research stations are found in the best locations in terms of soils and resources.

tions done by farmers (e.g., evaluation of the biological performance of the technology gap between experimental and farmers' yields, labour requirements, resource requirements, cost-benefit analyses). The most important factors in this on-farm research should be the extensionists and the leading farmer. Also, the researchers' participation is important, mainly in the evaluation activities and, especially, in methodological development and in the definition of measurement techniques to obtain reliable information. At this level of research, the participation of developers[3] is also critical to incorporate their inputs and viewpoints as well as make them aware of new technological advances.

Adoptive Research

After evaluating the performance of the new technology at the microlevel in the farmer's fields, the released[4] technology may or may not move rapidly in a zone, region or, country. This is strongly affected by the characteristics of the technology in question (superiority of new technology in productivity, availability of resources required for its implementation, cost-benefit advantage, range of technology, adoptability, etc.), as well as by the characteristics of the socioeconomic environment (farmers' choice, infrastructure, marketing, politically determined economic incentives, etc.).

At this macrolevel, the research should be mainly a joint effort of developers, extensionists, and researchers. The politicians should also play an important role in this type of research. They should be aware of the potential of the new technology, as well as the requirements in terms of the political decisions for the better achievement of development. The transfer of technology is a natural result of this integrated approach and its effectiveness only depends on the effective participation and communication (forward and feedback) of politi-

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3 Developers: officers of developing organizations (developing banks, farmers associations, cooperatives, etc.).

4 Superior technological components and techniques made commercially available to farmers at different levels of applied research activities.

cians, developers, farmers, extensionists, and researchers.

Network Approach

The apparently simple scheme for applied research (Fig. 2) is not so easy to implement in pasture research, especially when traditionally researchers, extensionists, and farmers are not together in the same development program. In addition, to incorporate the developers and politicians in the applied research process is certainly even more difficult. One way to facilitate the implementation of an effective pasture research program within this integrated approach is to organize and implement a network to suit the needs of coverage (ecosystems and farming systems), and at the same time gaining time and economics of scale.

The network approach as suggested in Fig. 3, should be expected to cover major off-station as well as on-farm applied research activities. This coverage should be done through defined sequential trials to provide a backbone to advance the research activities with new selected germ-plasm to reach the farmers appropriately.

After major germ-plasm screening that is part of the factorial research, minor screening (RT-A), adaptation trials (RT-B), management trials (RT-C), and animal productivity trials (RT-D), as described earlier are linked to the on-farm trials, regional trial E (RT-E), that is part of the adoption research. The full sequence of regional trials could take 12-17 years (Table 8). Flexibilities should be included for participants in network activities to advance more rapidly by avoiding some of the steps in this sequence. The soundness of these faster routes will depend strongly on the experience accumulated in networking, especially in the germ-plasm/environmental and germ-plasm/management interactions, as well as in the effective characterization of soil/plant/animal relationships at the station level and the appropriate recognition of farmers' needs and requirements. Data processing, information, and feedback also play a critical role. Contrasted with the longest route (Fig. 3), passing after major screening to RT-A, RT-B, RT-C, RT-D, and RT-E, which probably is logical for the more advanced institutions, the

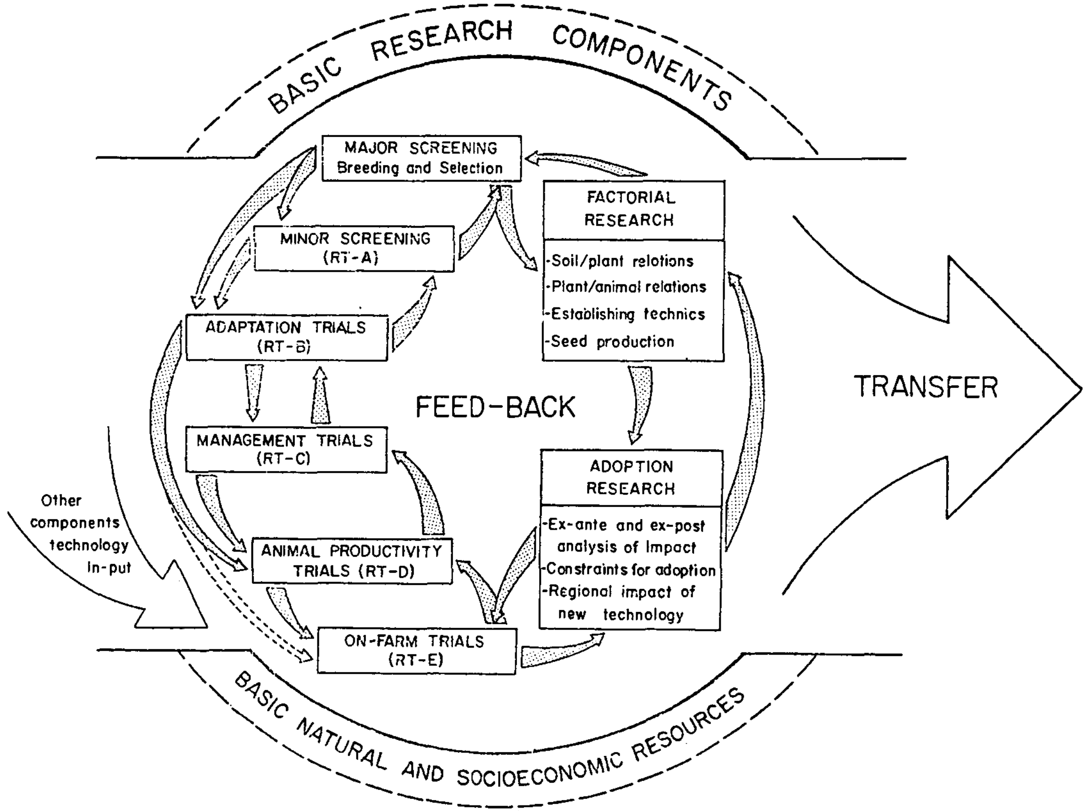

Fig. 3. The Network activities in a pasture applied research program.

Table 8. Time needed to conduct the different steps of pasture evaluation.

Type of trial	Time (years)
RTA = Introduction	2
RTB = Agronomic measurements	2
RTC = Pasture persistance	2-3
RTD = Animal production trials	3-5
RTE = On-farm evaluation of animal production systems	3-5

the shorter route will start with RT-B, passing to RT-D and/or RT-E saving in one specific location both time and resources.

Another way to visualize the organization of the Network in an applied pasture research program is to use the flow diagrams as shown in Fig. 4, where after diagnosis and characterization of the target area, constraints are defined and research strategies set. This scheme combines the well known steps of the farming systems research methodology and the steps and methodology followed in RIEPT (Li Pun and Zandstra 1982; Mateo and Li Pun 1983). The sequential trials within the network (RT-A to RT-E) provide a means of coverage of the applied research toward the integration of the new improved technology in farming systems.

In addition to the appropriate coverage of the target area, several benefits and economies of scale could be reached by applying the network approach: (a) effective exchange of information, (b) adjustment of methodologies to common resources, (c) catalysis of the reearch activities in a region or country, (d) capacity for extrapolation of results, and (e) more complete understanding of the environment/plant/animal/farmer complex.

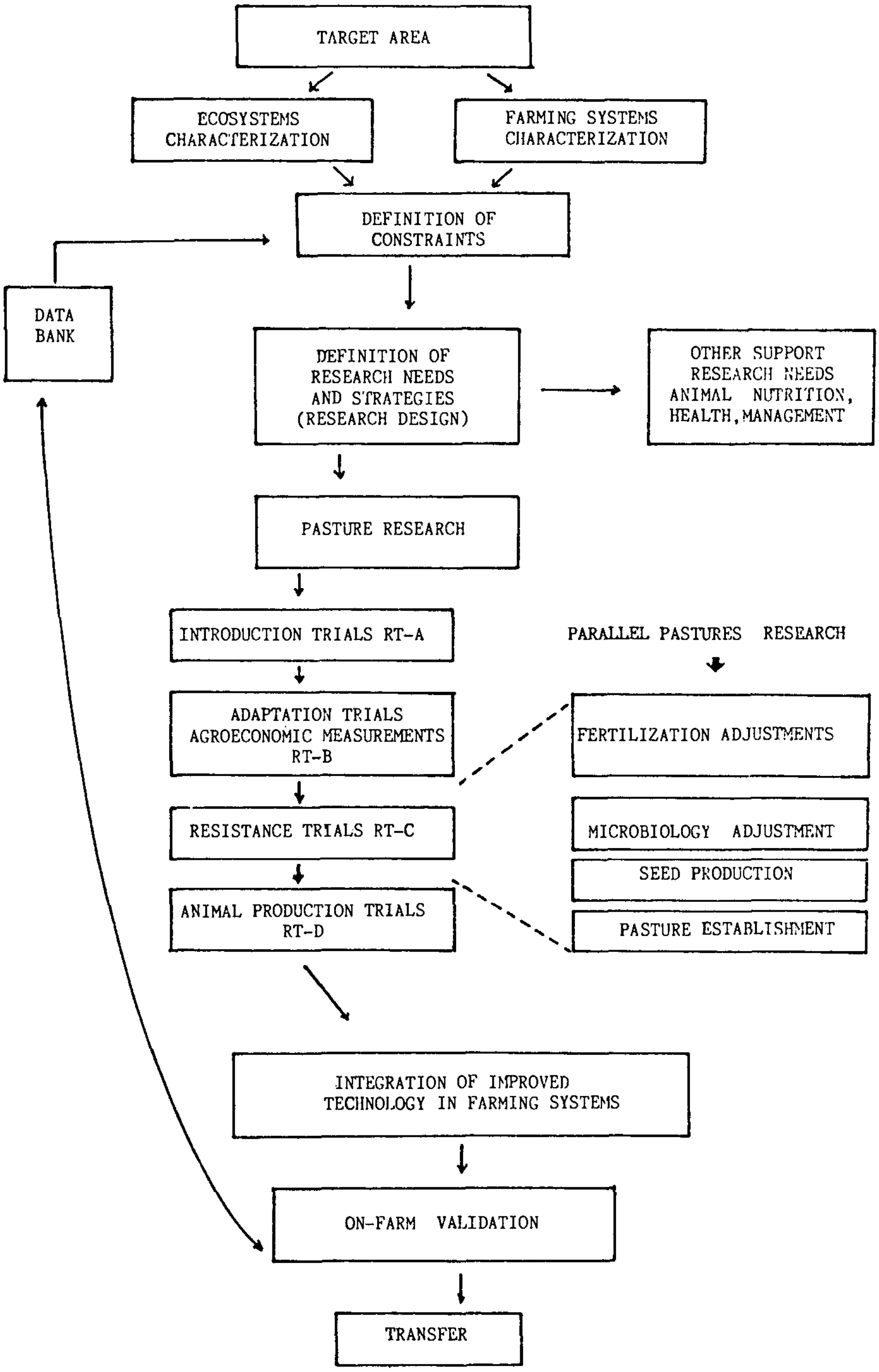

Fig. 4. Scheme for a national program for applied research on pastures.

In conclusion, networks are in fashion these days. In a recent consultation meeting at CIAT, some of the Latin American national program directors expressed their worries about networks. In particular, it was felt that they only have the name and not the organization for effective action on subjects of common interest and that so many networks are being developed in name only that their organizations and researchers are in danger of becoming entangled in a profuse web of ineffective networks. Effective networks require (a) a common interest and a defined research problem, (b) sources of basic research in components, (c) understanding of the diversity of natural and socioeconomic resources, (d) effective coordination and organization based on consultation with participants, (e) continuity of activities, and (f) effective exchange of information.

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DISCUSSION SUMMARY AND RECOMMENDATIONS

RESEARCH PRIORITIES AND FUTURE STRATEGIES ON GERM-PLASM COLLECTION (MULTIPLICATION, STORAGE, AND DISSEMINATION)

A cooperative network was envisaged involving a regional genebank interacting with national institutions to facilitate the exploitation of native forage germplasm resources to a degree that could not be achieved individually.

Collection

- Priorities should be assessed on the basis of development of agriculture in a country, on the degree of current destruction of available resources, e.g., through overgrazing, and on the degree of population pressure on natural cultivars. In some cases, improvements in agriculture result in the replacement of the traditional cultivars, making the collection of indigenous species an important priority. Priority also depends on the extent of actual activities, on requests by countries or organizations.

- Specific or general collection depends on the degree of urgency. Where degradation is slight, it could be specific but where degradation is high (e.g., in highly populated areas), general collection may be necessary.

- Collection and evaluation must go hand-in-hand. The former is of little value by itself.

- It was strongly stressed that international agencies responsible for the regional genebanks should encourage the development of national institutions in relation to genebanks. International and national institutions should use the same strategies and documentation of collection.

- Rhizobia samples should be collected with legume collections where possible, although the difficulties are acknowledged. Existing facilities and experiences could be used for the propagation and storage of these collections within the limits of current resources.

- It was also acknowledged that collection at the farm level necessitates a knowledge of the local language or a first-class interpreter.

- It was strongly felt that forage and crop collection should not be conducted simultaneously as there is a tendency to neglect one of the two.

Multiplication

- The regional genebank should be responsible for purification, initial increase, and long-term storage of small quantities of the collected material for posterity. Subsequent increase of larger quantities for evaluation and utilization in national and regional pasture-improvement programs should be the responsibility of the national institutions involved.

- The regional genebank provides the national institutes with collected germ plasm for further evaluation with the expectation that it will receive back at least the same quantity as issued together with the information gained.

- There is need for a regional seed-production project as a matter of priority. Some countries in the region have virtually no seed "industry," others have substantial industries and channels for the availability of seeds. It is suggested that IDRC investigate the feasibility of such a project on a regional basis involving other international agencies (e.g., FAO) and outside technical assistance. A start should be made by identifying species badly needed on a commercial scale by certain countries and countries that are potential suppliers.

- Documentation is essential throughout the whole multiplication process and should be of a standard format that all participants can use and even conform with.

Storage

- The regional genebank should have long-term storage facilities (-20 °C). Base and active collection should be kept separate but stored under the same conditions.

- Moisture contents of forage seeds for long-term storage are probably between 4 and 6%, but studies could be done on the subject by the regional genebank with benefits.

- Long-term storage demands high-quality, perhaps expensive, containers to exclude moist air. Laminated foil bags, or cans, from which the air can be extracted are essential.

- It was recommended that national institutes should have short- and medium-term storage facilities, with long-term storage only if they can afford it. For medium-term storage, +4 °C, controlled humidity, and a seed moisture content of 8-10% are recommended. Screw-top containers, preferably not glass, should be adequate.

- Periodic checks on viability of seeds stored under long-term conditions have to be done.

Dissemination

- All available data should go with the seed when issued. This requires standardized recording at regional and national levels.

- Any seed released (for commercial use) should have a sample of breeder's seed pedigree retained for storage at both the regional and the national level; for long-term storage at the former and medium-term at the latter. This is a "little job" for which someone has to be specially detailed. At this stage of development in the region, released cultivars should be grown under certification only where necessary.

- It may be necessary to restrict dissemination to some extent, priority being given to responsible national institutions, or at a lower level, to responsible companies or bona fide farmers. Requests from unknown or "odd" sources may have to be checked through national institutes.

- Feedback on the fate of seed issued should be a regular part of dissemination. At the national level, i.e., down to the farmer level, extension services would be expected to play an essential role here.

SELECTION AND EVALUATION METHODOLOGIES

The group discussed in detail the methodologies for evaluation of forage species and recommended the following.

Nurseries: The recommended procedures for nurseries are as follows. Fertilize the nursery area on the basis of local experience in soil analyses to eliminate known deficiencies. Sow seeds in rows approximately 5 m long and at least 1 m apart. Inoculate legume seeds and irrigate as necessary to ensure emergence. Weed for the first season at least. Records kept (every 4 weeks ideally): germination (separate record) stand, vigour, height and spread, flowering, pests and diseases, seed set. Height and spread are specific measurements, whereas others are scored 0-5. Legume nodulation is scored once. Reap seed and keep record of yield.

In the dry season plots should be cut back to 15 cm (legumes) and 10 cm (grasses). Dual-purpose forage crops could follow the same evaluation process. Use standard forms, but members can keep additional records as they wish. Keep 2 years of nursery records, then allow livestock access to nursery to assess acceptability.

Sward Evaluation: This method depends on the objective of the pasture. This involves plots for cutting, strips in natural grassland. There is a need to evaluate similar types together. Repeat at several sites.

Cut Plots: Straightforward agronomy. The group suggested plots of 4 x 4 m grass, 3 x 3 m within for cutting by cut by hand and recommended 4 replications. The primary treatment is a comparison of a number of potential cultivars. Mixtures may need to be of grasses and legumes, or pure grasses plus fertilizer. For screening legumes use two grasses in mixtures, for screening grasses use two legumes. Most likely treatments are with or without fertilizer (in high and low rate). Common defoliation times should be examined.

Experimental Design: Simple designs are desirable, e.g., randomized block.

Measurements: Dry matter (DM) yield, annual and seasonal, nutritive value - crude protein (CP) and in vitro digestibility (IVD). Desirable at some stage to allow stock access to check acceptability. Persistence should be measured for a period of 3 years during which dry matter (DM) yields should be taken. Other records may be necessary.

Strip in Native Grassland (legumes only): (As in Cameron's paper, this publication.) Strips of 50 cm wide, 4 m long plots with 2 m between them. Treatments to be included are (a) legume strains of the same type, (b) fertilizers at 0 and at likely level. The most desirable design is split-plot with fertilizer, main plot and strains as subplots. The records to be taken should be at monthly intervals and include plant numbers, DM yield after a period of rest, removal during grazing, herbage samples for CP and IVD analyses. The minimum duration of such experiments should be 2 years.

Further Evaluation

Fewer species, larger plots, and a larger number of treatments; at several sites, DM yields, fertilizer effects, detailed chemical analyses, and animal acceptability and digestibility; replicates - as before, duration - at least 3 years, and design - simple as possible.

Aim to reduce the list to a few "best" strains for the next stage. Further agronomic experiments at this stage will examine such aspects as establishment and seed production. Untested strains may need to be screened for toxicity.

Final Stage: Animal production trials involving 3-5 similar potential cultivars. Procedures must be related to likely use. It is difficult to define procedures as likely use may vary, e.g., milk, meat, or wool. The important treatments are stocking rates and nitrogen fertilization rates (especially in "cut and carry" systems). The experimental designs should either be standard replications or regression. With the latter, more treatments are desirable. A minimum of 3 years of experimentation is recommended.

Strategies

It is recommended that these guidelines be followed to the extent of using standard forms and methods. This can be facilitated by coordination. A clearinghouse for seed distribution and analyses of data is desirable. Although ILCA may effectively distribute seeds, there may arise problems with data analyses as ILCA might publish the results.

There is a need for a training workshop for plant introduction and evaluation officers. This will help to increase contact and cooperation between workers in similar fields.

ESTABLISHMENT AND MANAGEMENT

The group discussed in detail the constraints faced by farmers in establishing pastures and also in managing and harvesting. In the case of the traditional livestock sector, it was appreciated that, due to the low returns from livestock in the existing environment and with the unimproved Zebus/Sangas and small ruminants, the agropastoralists are discouraged from establishing improved pastures. The existing marketing system was singled out as a main factor, but there was no general agreement. It was felt that the existing land tenure and market systems involving grading evaluation, livestock transportation, and channeling of livestock products are not in favour of the development of the traditional/communal sector. Further, it was also felt that there is a need to generate appropriate technologies for small-scale farmers for pasture-improvement programs. For large-scale operations, it was felt that the equipment for pasture establishment needs improvement. Shortage of personnel was also identified as another bottleneck.

With these in mind, the following were the recommendations of the group:

- There is a need to modify land ownership or land user right to create responsibility over land under-grazing as the present communal grazing land use discourages pasture improvements. In the process of making these modifications, it was felt that law enforcement alone without community involvement only creates enemies. Therefore, it was strongly felt that communities must be involved in the whole process.

- Reformations in land tenure/user rights should go together with rational grazing schemes, e.g., rational grazing patterns to allow periods of rest.

- Fencing and paddocking facilitates rational grazing patterns. It was recommended that governments should sponsor fencing where communities agree to follow grazing schemes.

- Little information exists on the establishment of improved pastures to fit local systems, e.g., (a) under-seeding arable crops, (b) range improvement by reinforcement, and (c) fertilizer requirements. Therefore, there is need for research in these areas.

- The group noted that methodologies for evaluation of range conditions vary greatly. It was felt that there was a need to form a committee comprising range experts and biometrians on methodologies. This will go a long way in facilitating a greater exchange of scientific experiences.

- The group felt the need for evolving appropriate technologies for seed production for use by small-scale farmers. Research should look into this.

- It was noted that the available tools for seedbed preparation consist mainly of ploughs and harrows. Such tools are not available to small farms and, hence, the need to develop simple tools for use by peasants. This should go together with a training program for the maintenance of these simple tools.

- It was felt that if the small-scale farmers are to benefit from improved pastures, they should be able to harvest and conserve forages. It was recommended that research be done on systems of cutting, collecting, and conserving (silage or hay) cultivated forages and field crop residues.

- For large-scale farms it was felt that the technique of pelletization of seeds for aerial seeding be investigated.

RESEARCH FOR SMALL-SCALE/SMALL PRODUCERS PASTURE IMPROVEMENTS

It was recognized that, in most cases, country problems started with an inadequate extension ability because of a lack of trained personnel with a personal commitment to the need for change, lack of backing from research staff who rarely had much experience or flair for the special problems of the communal range systems, and lack of involvement of local community groups in the identification of the basic problems.

Reviewing the brief, it was concluded that, for practical purposes, the problem of the interrelationship of traditional livestock keepers with their environment could better be viewed as one of nutrition rather than overstocking. It was further agreed that, in most cases, there was an alarming loss of grazing land to arable needs. Thus, two distinct aspects of remedial treatment were recognized. The first included the possibilities of improving grazing (a) through paddocking and, thus, resting and restoration periods; (b) through reseeding techniques of the existing range lands; and (c) establishment of permanent pastures. The second included the possibilities of increasing biomass for livestock consumption from the arable lands themselves: (a) better conservation of crop residues, (b) growing of high-quality bulky annual legumes that would balance other residues and roughages, (c) growing of fodder crops as a catch crop or intercrop or from purposely planted forage species to provide maximum bulk and quality, and (d) pasture establishment on old reverted arable lands, which probably had a better chance of successful establishment than in the grazing areas that are often found in poorer soil environments.

The problem of pasture improvement in circumstances when the basic problem was one of known excess of stock numbers was discussed. It was noted that in the past extension has been left to look at this problem. It was felt that researchers should assist extension staff in this area and it was also recommended that livestock-keeping communities should be involved in research and in drawing up possible solutions to their problems.

To facilitate this interaction among the researchers, extension workers, and farm communities, a holistic approach is required. A farming-systems team approach would be suitable provided such a team included extension staff of experience, land-use planners, sociologists with economic or farm-management training. Such a team would involve the people from the beginning through local committees and would determine proper planning of arable areas, where any pastures might best be introduced, how to tackle range improvement, and make the best use of water availability with possible reticulation for both human and livestock use. The need was for a multidisciplined team approach.

It was noted that in some countries, notably Kenya, Tanzania, and Malawi, small-scale dairying producion is growing and gaining importance, but the lack of appropriate pasture technology is a constraint to production. Furthermore, the availability of good-quality forages enhances animal productivity and reduces feed expenses. It is, therefore, important that research be conducted with the objective of finding suitable species/strains that yield well and are of good quality. Appropriate pasture-management practices and forage conservation technologies need to be studied.

ORGANIZATIONAL ASPECTS

The group recommended to the plenary session that:

- A pasture network be formed for Eastern and Southern Africa.

- The network will deal with such general problems as communication, finance of research, germ plasm, training, support services, such as analysis of data, consultancies, etc., and such other topics as this meeting recommends.

- A steering committee composed of five members be chosen by this plenary session whose function will be to organize and establish the pasture network. These members should be broadly representative of regions and specialities.

- This steering committee will meet today (21-9-84) to draft a funding proposal for IDRC to support the organizational meeting.

- The organizational meeting should be held within 3 months and make recommendations on the form of the network and membership, leadership of the network, specific functions of the network, linkages with IARCs and other networks, and plan of action and budget.

- Upon the formation of the network, the five members will then become the first working committee of the network. Other interested organizations will be co-opted to participate, for example, IDRC for funding and ILCA and ACIAR for research support.

- The working committee will be responsible for drafting a proposal for financial support of the network by IDRC. The proposal will include a coordinator and such other support staff as required.

- The coordinator will be a member of the working committee.

- An annual meeting is recommended to deal with specific scientific subjects as suggested by the network members to help manage the network and to elect new working-committee members as required. All participating countries would be represented.

- The pasture network should encourage the formation of national networks that would include all of those interested in forage and that would be considered to be members of the pasture network.

- That the network should look at associations and societies available on national levels to facilitate better flow of information in the eastern and southern region.